MOTOR TRUCK

and

AUTOMOBILE

Motors and Mechanism

A Practical Illustrated Treatise on the Power Plant and Motive Parts of the Modern Motor Vehicle, for Owners, Operators and Repairmen.

BY

THOMAS H. RUSSELL, A. M., M. E.

with

Numerous Revisions and Extensions

BY

JOHN B. RATHBUN, M. E.

Consulting Engineer and Instructor
Chicago Technical College

CHARLES C. THOMPSON CO.
CHICAGO, U. S. A.
1917

gen. lib.
8-19-30

PREFACE

The purpose of this book is to present in a clear, concise manner the essential facts regarding the construction and operation of the modern automobile and motor truck. Included in the text are many useful hints and rules for locating and repairing the many ills to which the motor vehicle is heir. Special attention has been paid to the operation and repair of the Ford chassis, whether used as a pleasure car or truck. This makes the book more than ordinarily valuable to the owner of this popular little car, as the Ford has many peculiar features of construction not used on other automobiles.

In principle of construction the motor truck does not differ greatly from the pleasure car, but the differences in detail are fully described in a separate chapter. Electric cars and trucks are also included.

Beginning with a simple description of the relation between the parts of an assembled car, the reader is led in easy and logical steps to a detailed analysis of the construction of the various items, their maintenance and repair. The construction and operation of the gasoline motor receives particular attention. Such new features as the electric gear shaft, vacuum fuel feed, and the eight-cylinder motor are described in detail.

Ignition and electric self-starting devices found on every modern machine are given particular attention as the electrical equipment is generally the least understood feature of the construction. A comprehensive illustration of the electrical circuits is included in the chapter on Self-Starting.

CONTENTS

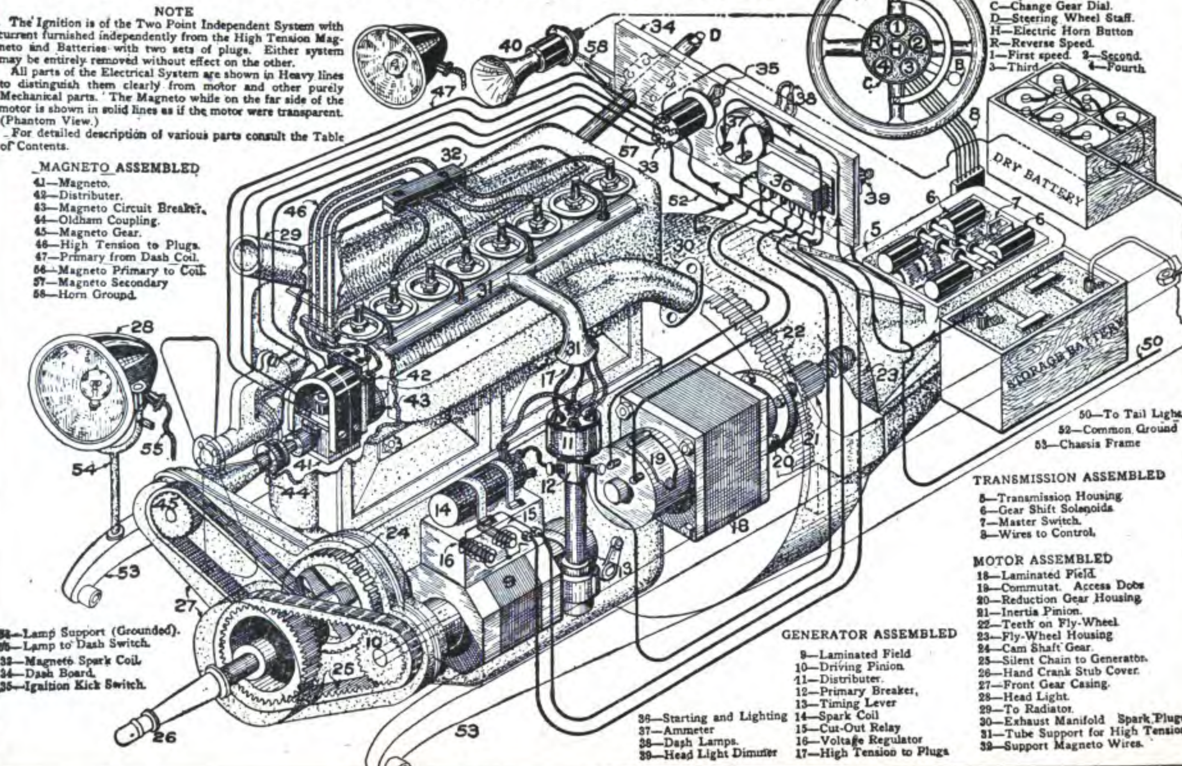
ELECTRICAL SYSTEM OF A MODERN AUTOMOBILE

NOTE

The Ignition is of the Two Point Independent System with current furnished independently from the High Tension Magneto and Batteries with two sets of plugs. Either system may be entirely removed without effect on the other.

All parts of the Electrical System are shown in Heavy lines to distinguish them clearly from motor and other purely Mechanical parts. The Magneto while on the far side of the motor is shown in solid lines as if the motor were transparent. (Phantom View.)

For detailed description of various parts consult the Table of Contents.



MAGNETO ASSEMBLED

41—Magneto.
42—Distributer.
43—Magneto Circuit Breaker.
44—Oldham Coupling.
45—Magneto Gear.
46—High Tension to Plugs.
47—Primary from Dash Coil.
56—Magneto Primary to Coil.
57—Magneto Secondary
58—Horn Ground.

54—Lamp Support (Grounded).
55—Lamp to Dash Switch.
33—Magneto Spark Coil.
34—Dash Board.
35—Ignition Kick Switch.

36—Starting and Lighting
37—Ammeter
38—Dash Lamps.
39—Head Light Dimmer

GENERATOR ASSEMBLED

9—Laminated Field
10—Driving Pinion.
11—Distributer.
12—Primary Breaker,
13—Timing Lever
14—Spark Coil
15—Cut-Out Relay
16—Voltage Regulator
17—High Tension to Plugs

STEERING WHEEL ASSEMBLED.

A—Steering Wheel Rim.
B—Spark Lever.
C—Change Gear Dial.
D—Steering Wheel Staff.
H—Electric Horn Button
R—Reverse Speed.
1—First speed. 2—Second.
3—Third. 4—Fourth

50—To Tail Light.
52—Common Ground
53—Chassis Frame

TRANSMISSION ASSEMBLED

5—Transmission Housing
6—Gear Shift Solenoids
7—Master Switch.
8—Wires to Control.

MOTOR ASSEMBLED

18—Laminated Field.
19—Commutat. Access Dobs
20—Reduction Gear Housing
21—Inertia Pinion.
22—Teeth on Fly-Wheel
23—Fly-Wheel Housing
24—Cam Shaft Gear.
25—Silent Chain to Generator.
26—Hand Crank Stub Cover.
27—Front Gear Casing.
28—Head Light.
29—To Radiator.
30—Exhaust Manifold Spark Plugs.
31—Tube Support for High Tension.
32—Support Magneto Wires.

CHAPTER I.

ESSENTIAL PARTS OF A MOTOR CAR.

We may classify motor vehicles under four different types:

(1) Those propelled by means of internal combustion engines.

(2) Those propelled by steam engines.

(3). Those propelled by electric motors supplied with current from a storage battery.

(4) Those propelled by electric motors, using current generated on the car by means of an internal combustion engine.

It is with the first that we shall have mostly to deal, for steam and electric cars, though successful in operation and having many firm friends and advocates, are at present in the minority.

In Figs. 1 and 2 we show how the arrangement of the various parts of the motor car is carried out.

In Fig. 1 we have a chain-driven car, and in Fig. 2 a gear-driven car. The difference between the two is small. We will take first a chain-driven car, and in most cases we have given the same reference letters to the same parts in Figs. 1 and 2. A is the engine—in this case a four-cylindered engine (it may, of course, be of one, two, three, four, six, or eight cylinders, and may be arranged differently as regards the inlet and exhaust from the method shown in our diagram). B is the flywheel of the engine and this may be regarded as the point where the power is transmitted from the engine to do the work of propelling the car: Inside B is the female

portion of a clutch, the male portion being shown at C. This clutch is for the purpose of connecting or disconnecting the engine to or from the transmission mechanism which transmits the power to the road wheels. D is a shaft which is driven by the male member C of the clutch when it is in engagement with the female member B. It is kept in engagement by means of a spring shown diagrammatically in our illustration. It may be arranged in a variety of ways, described in greater detail under the heading Clutch.

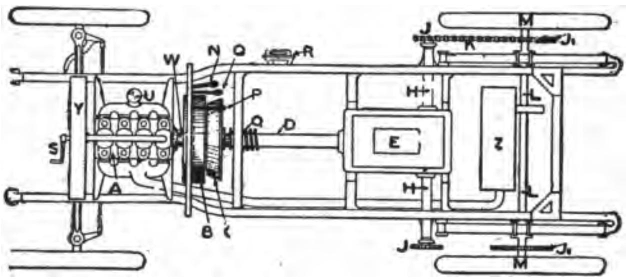


FIG. 1.—DIAGRAMMATIC PLAN OF MOTOR CAR WITH CHAIN TRANSMISSION.

A, Engine.
B, Fly-wheel and female portion of clutch.
C, Male portion of clutch.
D, Transmission shaft.
E, Change speed gear box.
H, H, Countershaft.
J, J, Front chain sprockets.
J, J, Back chain rings.
K, Driving chain.
L, L, Fixed axle.
M, M, Back road wheels.
N, Accelerator pedal.
O, Brake pedal.
P, Clutch pedal.
Q, Clutch spring.
R, Brake and change speed lever quadrant.
S, Starting handle.
U, Carburetter.
W, Engine or crank shaft.
Y, Radiator.
Z, Exhaust Muffler.

The internal combustion engine being incapable of starting until the crank shaft has been revolved, there is a starting handle S in front of the car which is put into communication with the crank shaft, but which automatically comes out of engagement as soon as the engine is started.

Y is the radiator, placed in front of the engine; sometimes it has a fan behind it, at other times the flywheel of the engine forms a fan, the object being to accelerate the speed at which the air is drawn through the radiator for cooling purposes. U represents the position of the carbureter on the inlet side of the engine. The carbureter, of course,

may be placed at either side of the engine, and sometimes, where the inlet and exhaust valves are all on one side, it is placed on the other side on a pipe which leads through between the two pairs of cylinders to supply them with gas. W is the crank shaft, to which the flywheel B is rigidly secured.

The parts which we have described represent the power-generating plant. We will now describe that portion which is purely for transmission purposes. D is a shaft coupled to the male portion of the clutch C. This shaft is only rotated by the engine when the clutch is in engagement. It then drives through into the gear box E. In the gear box is provided a change speed gear mechanism (see Change Speed Gear), and also the differential gear and the bevel wheel, by means of which the power is transmitted from the longitudinal shaft in the gear box to the cross shafts H, H, known collectively as the countershaft, which is arranged transversely in the frame. The ends of these shafts carry sprocket wheels J, J, these sprocket wheels being connected by means of the chains K to larger sized sprocket wheels attached to the hubs of the rear wheels. These sprocket wheels are marked J1, J. L, L is a solid forged axle carrying at its ends the road wheels M, M, which revolve about it.

Z is the muffler, into which the exhaust gases from the engine flow.

There are three pedals shown just over the clutch. P is the clutch pedal, by depressing which the clutch is taken out of engagement. O is a pedal which operates a brake, generally on the countershaft. N is the accelerator pedal used to hold up the governor, and to thus allow the engine to attain its highest speed.

The method of arranging a motor car as we have described is one of the earliest, and is still used in a very great number of up-to-date and high-powered cars. The chain transmission, however, although it has many advantages, is often noisy, and in the more modern cars using this type of transmission chain cases have been fitted not only to deaden the

noise, but also to protect the chain from dirt and to insure its proper lubrication.

In Fig. 2 we show in diagrammatic form a representative arrangement of a car in which the transmission is by gearing instead of chains, and cars using this method are known as gear-driven cars.

So far as the engine, the clutch, and the shaft D go, this arrangement is practically the same as that in a chain-driven car, but the gear box is so arranged that there is no

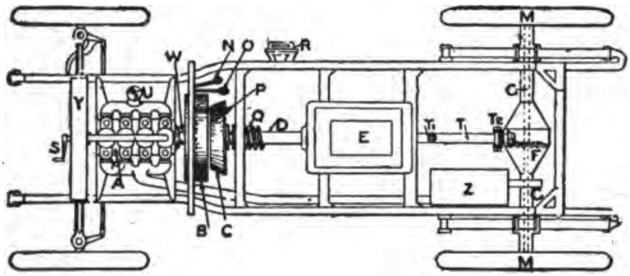


FIG. 2.—DIAGRAMMATIC PLAN OF MOTOR CAR WITH LIVE AXLE OR GEARED TRANSMISSION.

A, Engine.
B, Fly-wheel and female portion of clutch.
C, Male portion of clutch.
D, Transmission shaft.
E, Change speed gear box.
F, Differential.
G, G, Live axle.
N, Accelerator pedal.
O, Brake pedal.
P, Clutch pedal.
Q, Clutch spring.
R, Brake, and change speed lever quadrant.
S, Starting handle.
T, Cardan or propeller shaft
T1, T2, Universal joints.
U, Carbureter.
W, Engine or crank shaft.
Y, Radiator.
Z, Exhaust Muffler.

transverse shaft in it, and it does not contain the differential gear. Instead, it transmits the power directly either from the primary or the secondary shaft (see Change Speed Gear) to a differential gear which is incorporated inside tne case which forms the rear axle. As the gear box E is attached directly to the frame of the car, and as the axle which carries the road wheels M is attached to the car through the medium of springs, the relative position of the rear axle and gear box would be constantly altered, owing to road inequalities. In order, therefore, to transmit the power from the gear box E to the differential gear inclosed in the case F, some form of

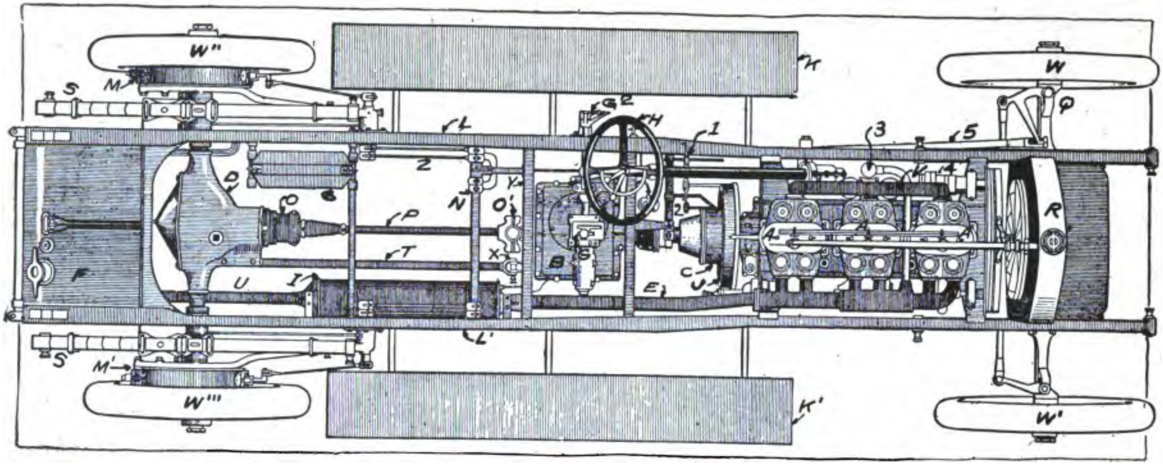
shaft must be used which will allow of movement up and down and sideways, the up and down movement being the most pronounced. This shaft is shown at T, and is known as the propeller shaft. It has a universal joint T1 at its forward end, so that the rise and fall of the back axle relatively to the frame will not affect the transmission of the power. In some cases the propeller shaft has a universal joint at either end, as in our illustration, and can then be described as a cardan shaft. The rise and fall, in the case of the arrangement shown as at Fig. 1, where chains are used to transmit the power, is allowed for by the chains themselves.

The power, being transmitted to the bevel wheel inside the differential case F, is transmitted from the differential gear to the road wheels by means of shafts shown in dotted lines at G. These shafts run inside the hollow axle shown, and, at their ends, are anchored to the wheels M, M.

Change Gears or Transmission.

Unlike the steam engine, the gasolene motor does not pull well at low rotative speeds, and for effective work must not be allowed to drop below a certain limit whether the car is traveling fast or slow. To obtain a fair engine speed with a resulting heavy pull at the road wheels, it is necessary to change the relation between the revolutions of the engine and road wheels. This is done by either gears or some equivalent device, so arranged that the ratios can be temporarily changed.

There are several ways in which the gears can be arranged, the principal systems being the "planetary" and the "sliding" types. Both systems, however, have in common the ability to increase the leverage of the engine over the road wheels, and to allow the engine to run faster or slower in regard to the wheels. By shifting a set of gears a small gear on an extension of the engine shaft is brought into active mesh with a larger gear on the driving shaft, thus allowing the engine to run faster. When the next higher speed is desired, the first gears



"LOCOMOBILE" SIX CYLINDER CHASSIS—(INDEPENDENT UNITS).

A, A, Cylinder Blocks.
B, Transmission Case.
C, Clutch.
D, Differential Gear
E, Exhaust Pipe.
F, Gasoline Tank.
G, Change Gear Lever.
H, Steering Wheel.
I, Muffler.
J, Fly-Wheel.
K, K', Running Boards.
L, L', Main Frame of Chassis.
M, M, Brake Drums.
N, Brake Equalizer Shaft.
O, O', Universal (Cardan) Joints.
P, Propeller Shaft.
R, Radiator.
S, S, Elliptic Springs.
T, Torque or Torsion Rod.
U, Exhaust Tail Pipe.
V, Intake Manifold.
W, W', W", W"', Road Wheels.

are shifted out of mesh and a second pair are mated which gives a smaller ratio. In normal running all gears are shifted out of mesh and the engine is directly connected with the road wheel driving shaft by means of a jaw clutch so that the driving shaft runs at engine speed. For the forward speeds there may be from one to three gear changes, according to the size of the car. The Ford has one geared and one direct speed. The heavier cars generally have two geared speeds and one direct speed.

As the gasolene engine cannot be reversed, there is a second gear combination that reverses the rotation direction between the engine and the propeller shaft.

A number of devices have been placed on the market intended to supplant the gear system. All of these provide a far greater number of speeds than would be possible with gears, but all of them have developed more serious faults than the old gear system.

Example of Modern Chassis.

The accompanying cut is an example of a modern 6 cylinder shaft driven chassis shown in plain view. From the description already given the relation of the parts can be readily traced. The six cylinder motor at the right has the cylinders cast in pairs, that is in groups of two as indicated by A-A-A, each letter being placed on a unit of two cylinders. The clutch C is mounted in the fly-wheel J, the stub end of the shaft running into the transmission or change gear box B. From the gear box B the propeller shaft P runs into the differential casing D on the rear axle. The gears in the casing are shifted by the lever G on the center of the gear box. K and K^1 are the running boards, and W-W^1-W^{11}-W^{111} are the road wheels. The steering wheel is indicated by H. Gasolene is stored in the tank F at the left, from which it is forced to the carbureter by air pressure. The exhaust gases from the engine pass through the exhaust pipe E to the muffler I. From I, the gases pass through U to the atmosphere. Two universal joints, O and O^1, are placed at either end of the propeller shaft

P so that the action of the springs when passing over rough roads will not interfere with the rotation of shaft. From D the power is transmitted through a bevel gear to the two rear road wheels W^{11} and W^{111}.

At the center and inside of the rear wheels are the brake drums M and M^1. A brake shaft N is provided with small levers (at upper end) which are known as "equalizers." These levers allow the pressure of the brake pedal 1, or the emergency brake lever G^2, to be transmitted to both the drums of the left and right road wheels with equal force. If the force on the drums were not equal, there would be excessive wear on the tires.

Unit Power Plant.

In the larger types the engine and transmission are arranged as two independent units. Both units in this construction are attached to the main frame through cross-members or by long arms. Due to the flexing of the chassis frame in passing over rough ground there is a continual change in the alignment of the engine and transmission shafts, making it necessary to place some form of flexible joint between the two units.

In practically all medium weight and light cars it is the practice to have the engine and transmission combined in one unit so that no flexible couplings are necessary. This reduces both the weight and number of parts, cuts down the fuel and maintenance expense and in addition makes the power plant shorter. A power plant in which the motor and transmission are combined as one part is known as a "Unit Power Plant."

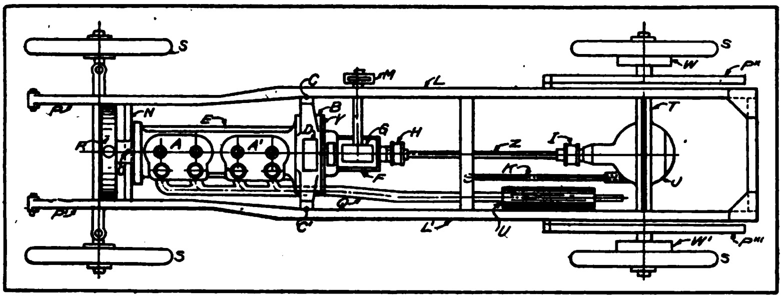
Three Point Suspension.

When a motor or transmission is suspended from the frame so that it is bolted to the frame at four points, every deflection or twist in the frame is transmitted to the engine or transmission, causing the shaft to spring and the bearings to bind.

To avoid this trouble, both the engine and the gear case are suspended at three points on the frame, the joints being rather flexible. Two points are attached to the outside members, while the third point is attached to the center of a cross member so that when the frame is sprung the engine will rotate slightly about the central third point. This rotation will, of course, prevent strains from being thrown into the engine or transmission.

The unit power plant is an ideal arrangement for the application of the three point principle as the arms are short and only one-half of the attachment points are needed when compared to the two unit system.

A four cylinder car is illustrated, the cylinders being cast in two blocks, A-A¹, two cylinders per block. The engine crank-



FOUR CYLINDER UNIT POWER PLANT.

The Engine Crank-Case E, the Transmission F, and the Fly-Wheel Housing Bare in One Unit Supported at the Points O, C, C′.

case E is cast in one part with the fly-wheel housing B, the fly-wheel being entirely enclosed with access through the removable cover D. The transmission casing F is bolted to the fly-wheel casing at Y, making the engine and gear casing a single unit. Two short arms C and C¹ attach the unit to the frame L-L¹, and as these are part of the large diameter fly-wheel housing they are comparatively short. The third point of suspension is at O on the frame cross member N. It is about O that the plant oscillates with the springing of the frame. The radiator R is often mounted on member N in

such a way that stresses from the frame are not thrown into the delicate core of the radiator.

The differential housing J on the rear axle tube T is connected with the transmission F by the propeller shaft Z, either one or two universal joints being attached at H or I. To prevent the rear axle from turning in a direction opposite to the rotation of the wheels because of the twist of the motor, a torque tube K is fastened rigidly to the differential and is pivoted on the transmission or cross-member at X. With some machines, the torque tube is omitted, the springs being designed so that they will take the torque to the motor. This is known as the "Hotchkiss drive." The springs are indicated by P-P^{1}-P^{11}-P^{111} and the wheels by S-S-S-S. The gear shift lever and segment is at M, with the brake drums at W-W. Muffler at U, exhaust pipe Q.

When laboring up a hill the twisting action of the rear axles is surprisingly great, and if the springs are to be used alone with the exclusion of the torque tube they must be substantially constructed. One thing in favor of receiving the torque through the springs is that fact that the flexing of the springs reduces the jar on the engine and transmission when starting suddenly or when striking obstacles in the road.

The Differential Gear.

In turning a corner the outside wheels revolve more rapidly than the inside. If both wheels were mounted on either end of a rigid axle one wheel would have to slip to make up the difference in speed.

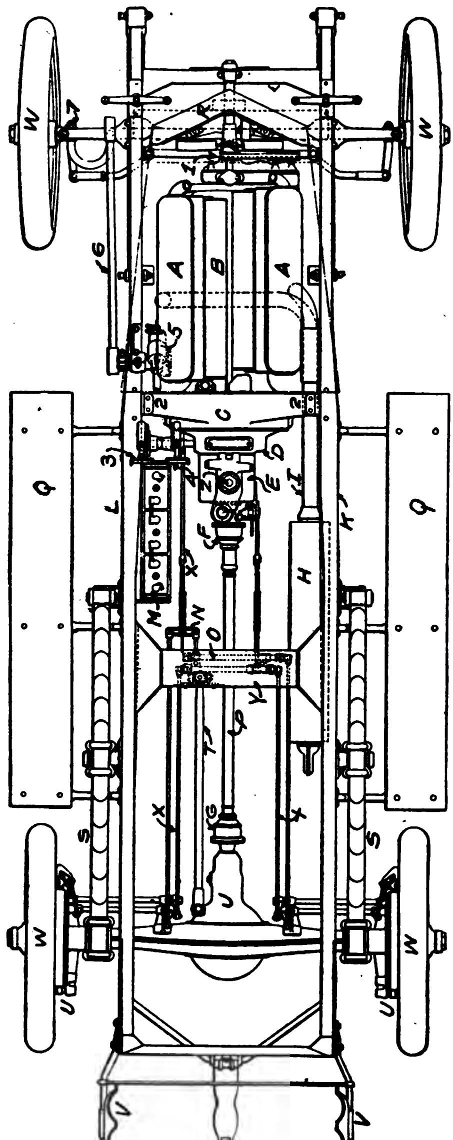
To prevent this trouble the rear axle in shaft driven cars is split with the inner ends connected through a system of gears, and the drive from the motor is applied to them in such a way that an equal amount of power is transmitted to each wheel. In the case of the chain-driven car the rear axle is left solid with the wheels revolving on the axle. The difference in the wheel speed is taken up by splitting the counter-shaft, and applying the differential gear at this point. The differential gear for this car is placed in the gear box.

With shaft drive, the end of the propeller shaft Z at J carries a bevel pinion that meshes with a larger bevel gear on the axle T. At this point the motor speed is reduced to the speed of the road wheels.

Radius Rods and Torque Tubes.

Owing to the fact that the axle tends to turn in a direction opposite to that of the wheels on either chain drive or shaft driven cars, it is necessary to prevent this twisting by either increasing the strength of the springs or by running a rod from the axle to the frame. In addition to the "torque" or twist, the pull of the chains on a chain driven car tends to pull the axle back and forth so that rod braces must be used to keep the distances constant between the transmission sprocket and the sprocket on the rear wheels. If this is not done, the varying distances will alternately tighten and slacken the chains.

When the car is of the shaft driven type, and only the twist is to be taken care of, a rigid rod K is run from the differential case J to the cross-member, the rod being joined to the frame cross-member. With a chain driven car, two rods run from each end of the axle to the frame, the frame ends of the rods being pivoted to the ends of the driving sprocket tubes. At the latter point they are provided with adjustments so that the chain can be kept at the proper tension. This is necessary as the chains stretch in service.



TWELVE CYLINDER "PATHFINDER" (UNIT POWER PLANT).

A, A, Cylinder Blocks.
B, Crank Case.
C, Fly-Wheel Housing.
D, Clutch Housing.
E, Transmission Case.
F, G, Universal Joints.
H, Muffler.
I, Exhaust Pipes.
J, Differential Housing.

K, L, Main Frame.
M, Storage Battery.
N, Brake Equalizer Rods.
O, Equalizer Shaft.
P, Pedal.
Q, Q, Running Boards.
R, Radiator.
S, S, Cantilever Springs.
T, Torque Rod.

CHAPTER II.

THE INTERNAL COMBUSTION ENGINE.

Internal Combustion Engine—This is the term which perhaps best describes the gasolene engine or motor with which most automobilists have to do. The principle of operation is based on the well-known facts that gasolene vapor or a fine spray of gasolene mixed with air forms a highly inflammable mixture, and that if this mixture be confined in a closed chamber and ignited by a flame or spark it will explode and expand. This is just what is done in a gasolene engine, the expansion being utilized as the motive power.

An internal combustion engine can use various kinds of fuel, but all of them are hydrocarbons. Heavy oils are not much used in motor car practice except on heavy vehicles; and, for the sake of description, we shall take it that the internal combustion engine used in the automobile will burn the very light hydrocarbon known as gasolene or petroleum spirit. It is from this that the gas is produced which is burned inside the engine.

The production of the gas from the hydrocarbon is the function of the carbureter. (See Carbureter.) The gas, being

expansive or explosive when ignited, is used to force a piston in a cylinder outward, this piston being connected by means of a connecting rod to the crank in such a manner that when it is forced out by the expansion of the gas in the cylinder it turns the crank; but the mechanism which is required to produce this apparently simple operation has other functions to perform. Before the gas can be exploded in the cylinder, it is necessary to draw it in, which means that there must be some opening in the cylinder through which it may pass. Before it can be exploded so that it will drive the piston down in the cylinder, there must be some means of closing up the entrance through which it has passed into the cylinder; while, again, before the operation of exploding the gas can be repeated, it is essential to get rid of the exhaust gases generated by the explosion. Also, some method of igniting the gas so as to cause it to expand must be provided. This latter requirement is usually attained by means of an electric spark.

Anoth r fact to be noted is that the explosive gas drawn into the cylinder will give out greater power when ignited if it is first compressed, and therefore the engine has also to perform the function of compressing the charge. Thus the engine has four different duties to perform:

First, it has to open the inlet valve and to draw in the charge.

Second, it has to close the inlet and compress the charge.

Third, it has to fire the charge so as to force the piston outward to do work.

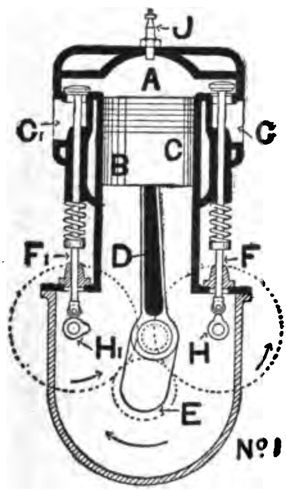
Fourth, it has to expel the burnt gases.

It is owing to these four operations having to be performed in sequence that the internal combustion engine, as used in automobiles, is known as a "four-cycle" engine.

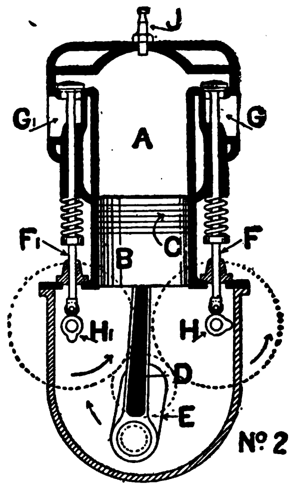
In our illustrations, Figs. 1, 2, 3 and 4, we show in diagrammatic form the type of internal combustion engine usually applied to automobiles. In arrangement of details engines vary considerably, but in the main features they are all practically alike. A is the cylinder and B is the piston. This piston B is capable of sliding freely up and down inside the cylinder A,

but it is provided with spring rings, which prevent any gas passing by it. D is the connecting rod which connects the piston to the crank E, which crank forms part of the engine shaft, and it is by the rotation of this that the car is driven. The piston B, when it is forced down in the cylinder, pushes round the crank E, and so turns the shaft. F and F1 are, respectively, the inlet and exhaust valves.

The gas from the carbureter enters at G, and, after having been ignited, is expelled through the port G1. The valves F



SUCTION STROKE.

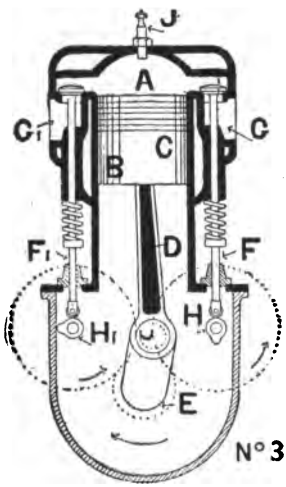


COMPRESSION STROKE.

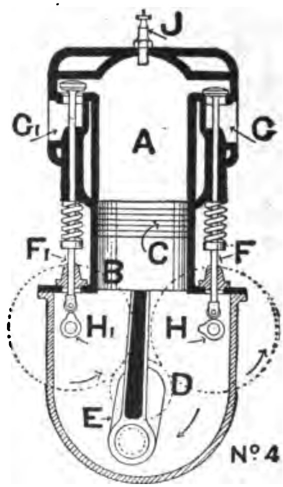
and F1 are operated by the engine itself by means of cams H and H1. These cams are carried on shafts which are driven by the engine crank shaft, but at half its speed. The dotted lines indicate the gear wheels on the two shafts and on the engine, by means of which the shafts are rotated. It will be seen that the cam on either of these shafts will lift its valve once in every two revolutions of the crank shaft.

In Fig. 1 we see that the cam has lifted the inlet valve F. At the same time the crank is in such a position that the piston is just descending in the cylinder. As the piston descends it acts as a suction pump, and draws in the gas from the carbureter through the valve port G. As soon as the

piston has reached the bottom of its stroke the cam H allows the valve F to fall on its seat. The flywheel on the crank shaft of the engine, however, through its stored momentum, continues to rotate the crank, and therefore the piston B is pushed back again into the cylinder (Fig. 2), but as now there is no exit from the cylinder, the gas inside it is compressed into the combustion space. This compression proceeds until the piston has reached the top of its stroke, and at this point a spark is caused to pass across the points of the sparking plug J. As soon as this occurs, the gas charge is ignited and ex-



POWER STROKE.



EXHAUST STROKE.

pands very rapidly, this expansion forcing the piston B down in the cylinder, and, through the medium of the connecting rod, turning the crank E. This is the power stroke (Fig. 3).

Immediately before the piston reaches the bottom of its stroke, the cam H1 lifts the exhaust valve F1, the inlet valve F, of course, remaining closed. The momentum of the fly-wheel carries the crank round and forces the piston back up the cylinder, it in turn forcing the exhaust gases out through the exhaust port G1. This is the exhaust stroke (Fig. 4). The engine is now in a position to perform the same cycle of operations as before, the next stroke drawing the piston down and

bringing in a fresh charge through the inlet G, which in turn is compressed, ignited and expelled as before. It will thus be seen that the engine during two revolutions has performed the four operations which are necessary to its proper working. The operations in sequence are as follows:

1. Down Stroke of the Piston.—Gas charge is drawn in.
2. Up Stroke of the Piston.—Gas charge is compressed.
3. Down Stroke of the Piston.—Gas charge, being ignited, is violently expanding.
4. Up Stroke of the Piston.—The exhaust gases are being expelled.

These four strokes of the piston, respectively, are known as the Suction, Compression, Power and Exhaust strokes, as indicated under the diagrams.

As the initial operation is to draw in a charge of gas, it will be seen that before the engine can be started it is necessary to rotate the crank shaft so that a charge is drawn in and compressed. This is then fired, and the engine will continue to operate automatically.

The action of the engine being understood from the study of the diagrams, we may now describe a typical automobile engine. The engine may have one or more cylinders. Four is, however, a general number, and the engine which we shall describe is a four-cylindered one. Our illustration is of a four-cylinder 35 H.P. engine. Fig. 5 shows it in cross-section through one cylinder; that is to say, the engine is shown cut in half through the cylinder and valve chests and through the crank case. Here we have again what was described in diagrammatic form in Figs. 1 to 4, but this is the actual arrangement of an efficient and modern automobile engine. Fig. 6 illustrates the same engine in section longitudinally, showing all four cylinders, crank shaft and flywheel. In both these diagrams we shall retain the same letters for the different parts as shown in diagrams Figs. 1 to 4. A is the cylinder; B is the piston with its rings C; D is the connecting rod, and E is the crank. The rings C around the piston are made of spring cast-iron, and by their own springiness they hold tightly up

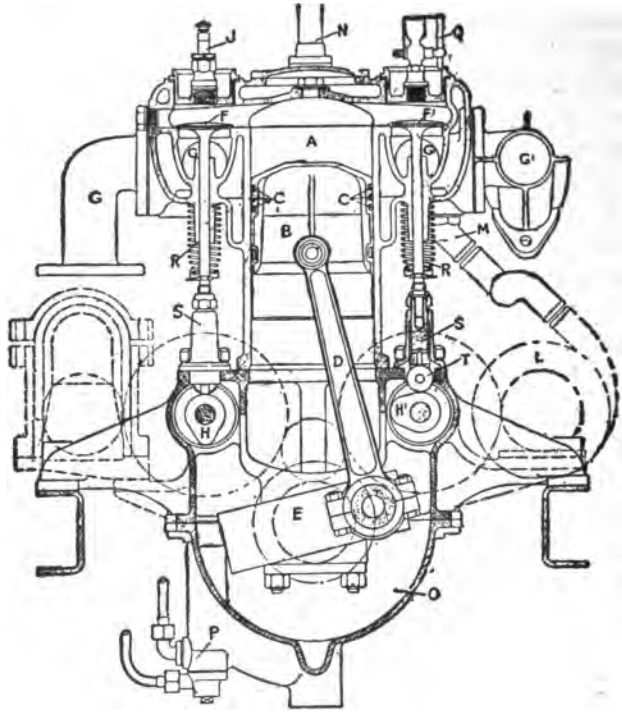


FIG. 5—CROSS SECTION OF A 35 H. P. ENGINE.
Index to Figs. 5, 6 and 7.

A, Cylinder.
B, Piston.
C, Piston rings.
D, Connecting rod.
E, Crank.
E1, E1, E1, E1, Crank pins.
E2, E2, E2, E2, Radial oil leads on big end bearings.
E3, E3, E3, E3, Holes for ejecting oil from big end bearings.
F, Inlet valve.
F1, Exhaust valve.
G, Inlet port.
G1, Exhaust port.
H, Inlet cam.
H1, Exhaust cam.
H2, Oil pump cam.
H3, Oil pump plunger.
H4, Spring keeping oil pump plunger in contact with cam H2.
H5, Automatic delivery valve to oil pump.
J, Sparking plug.
K, Water jacket.
L, Water pump (in dotted lines).
M, Water inlet.
N, Water outlet.
O, Crank case.
P, Oil pump.
Q, Compression tap.
R, R, Valve springs.
S, Valve plunger.
T, Roller on valve plunger.
U, Crank shaft.
V, V, V, Crank shaft main bearings.
W, Fly-wheel.
W1, Coupling on fly-wheel to crank shaft.
X, X, X, Oil leads to main bearings.
X1, X1, X1, Radial holes leading from main bearings to crank shaft centre.
Y and Y, Ball thrust bearings on forward main bearing to crank shaft.
Z, Pinion wheel on crank shaft.
Z1, Intermediate pinion.
Z2, One of the two gear wheels meshing with intermediate pinion Z1, and driving the inlet and exhaust cam shafts.
Z3, Oil sump from which oil is drawn to the pump.

against the wall of the cylinder in such a way as to prevent the passage of any gas.

An illustration of a piston is shown at Fig. 5A, though this is not the piston of the engine we are describing. It will be seen that there are three rings in grooves. These rings are slotted, as shown, diagonally. The diagonal slot in the center ring is not shown in our illustration, as it is behind the piston. The rings are normally bigger than the inside of the cylinder, but when contracted so that the diagonal slots are closed up, they will fit inside the cylinder, and will keep tight against it owing to their tendency to spring outward. These slots in

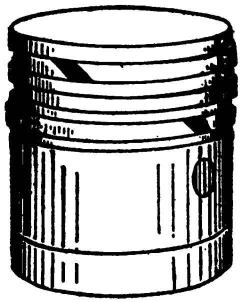


FIG. 5A—PISTON WITH RINGS.

the piston are kept an equal distance apart so as to preclude the passage of gas.

Returning to Fig. 5, F is the inlet valve and F1 the exhaust valve, while G and G1 are, respectively, the inlet and exhaust ports. H is the inlet valve cam, and H1 is the exhaust valve cam. These are on shafts which are driven by gear wheels from the engine, indicated by the dotted lines, but shown in position at Z, Z1 and Z2 in Fig. 6. J is the sparking plug. It will be seen that around the cylinder and around the valves there is a pocket or jacket K (Fig. 6). This jacket is used for keeping the cylinders at a temperature at which the engine will work efficiently, and water is circulated through the jacket from a pump, shown in outline at L, which forces water up through the pipe M and out at the top of the jacket through the pipe N. One jacket is used for one pair of cylinders, and

another jacket for the other pair, as is shown quite clearly in Fig. 6.

The crank shaft of the engine is carried in bearings which are fixed in the crank case O. This case is made of aluminum, and not only incloses the engine, cam shafts and gearing, but is also used to assist in the lubrication, which is a most important feature of all internal combustion engines. For this purpose there is an oil pump P driven by the engine, and shown in Fig. 7, to which we shall shortly refer. This pumps oil out of the bottom of the crank case O, and forces it to the various bearings of the engine. At Q is shown a valve, tap or cock, known as the compression cock. By opening this, kerosene can be injected into the cylinder for the purpose of facilitating starting, and at the same time the compression will be released, as, while this is open, the rising piston will force the gas or air out through this valve. It will be seen that the valves, both inlet and exhaust, are kept down on their seats by means of springs R, R. The cams lift them through the medium of plungers S, S, these plungers being arranged with an adjustable screw by means of which the lift of the valves may be regulated. At their ends they carry rollers, one of which is shown at T, and it is against these rollers that the cams work.

Referring now to Fig. 6, which shows the same engine in section longitudinally, we can see the arrangement of the cranks, connecting rods and the gear which drives the two cam shafts—one at either side of the engine. (Here, again, the same reference letters are used to denote similar parts to those in Fig. 5.) In this illustration it can be seen that the two cylinders of each pair are cast in one piece, with one water jacket K surrounding them. This view, of course, does not show the valve chambers, as these are on each side of the cylinders.

Shaft U, as will be seen, runs through three main bearings, V, V, V. These bearings are of special anti-friction metal. At the end of the crank shaft is the flywheel W, which is attached to the crank shaft by means of the flange, formed in

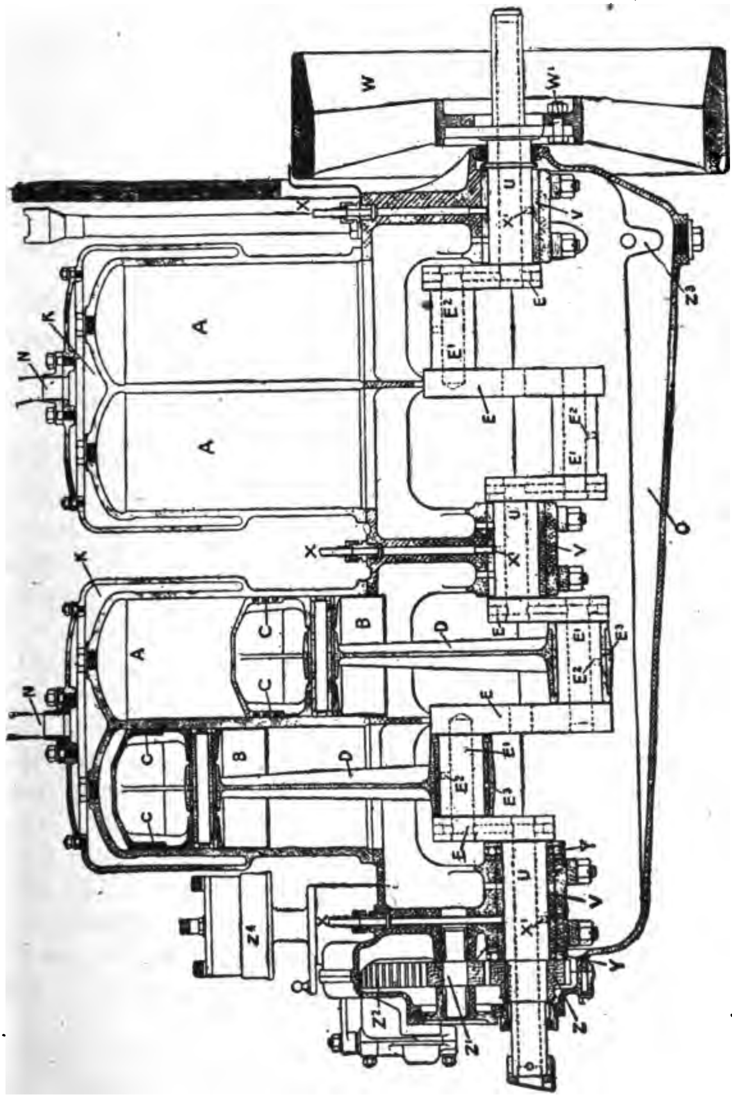


FIG. 6—LONGITUDINAL SECTION OF A 35 H. P. ENGINE.

one with the crank shaft, and the bolts and nuts, one pair of which is shown at W1.

The main bearings are carried in brackets which are suspended from the top of the crank case, and in order to lubricate these there are oil leads X, X, X. These oil leads are connected to the pump (which is illustrated at P in Fig. 5).

In order to take up any end-thrust on the crank shaft when the clutch is released, there are ball-thrust bearings shown at Y just behind the forward main bearing of the engine, and in front of this bearing.

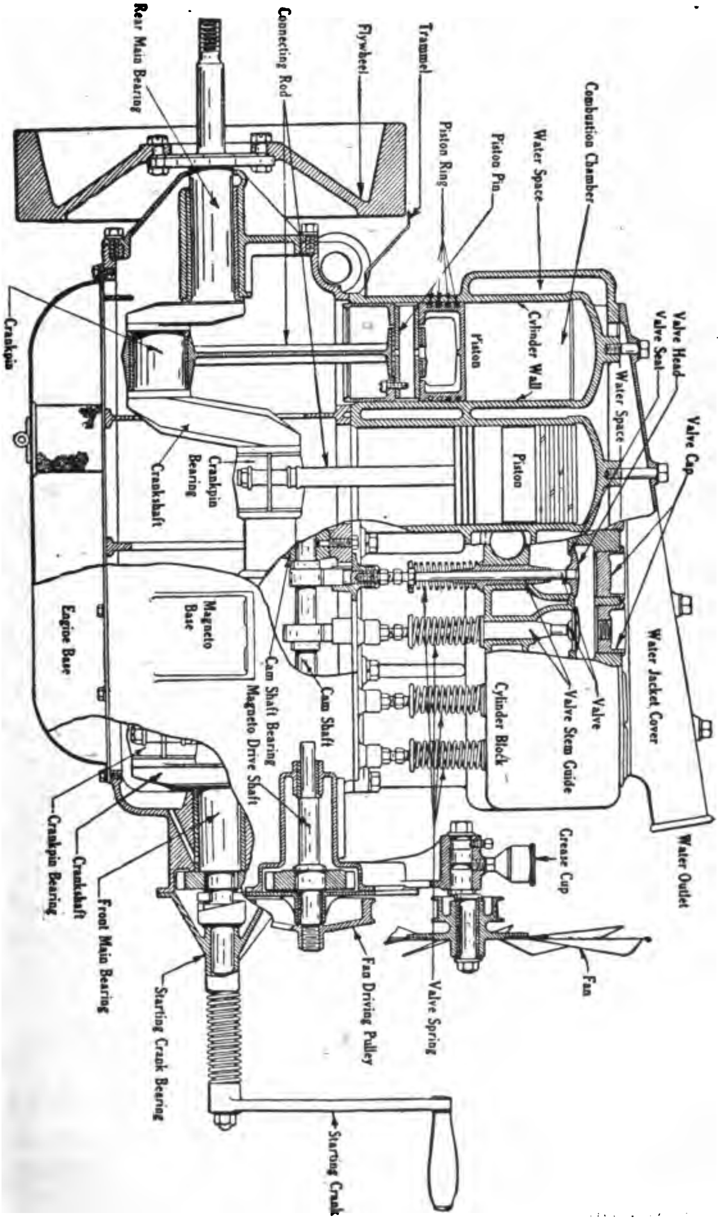
Two connecting rods D, D, from each pair of cylinders, drive on two crank pins between the center and forward bearings; and similarly between the center and after-bearing—this arrangement allowing a very wide bearing to the crank pins.

At Z is shown the pinion wheel which is attached to the end of the crank shaft U. This pinion wheel drives the intermediate pinion Z1, which, in turn, is in gear with two larger gear wheels, one of which is shown at Z2. One of these gear wheels is attached to the inlet valve cam shaft, and the other to the exhaust valve cam shaft.

The Eight Cylinder Motor.

With a single cylinder four-stroke cycle motor there is one power impulse in every two revolutions, and as this impulse must be heavy enough to carry the load during the remainder of the period there is a tremendous shock to the passengers and to the mechanism at every explosion. If two cylinders are used there is an impulse every revolution, the force of which need be only one-half of that of the single cylinder. The driving is more uniform because the power is applied more frequently and the stresses induced in the frame are only half of those in the first case.

Therefore, increasing the number of cylinders for a given power decreases the shock per individual impulse, giving better explosion balance and better and smoother drive or "torque." In addition to giving better explosion balance it is



TYPICAL FOUR CYLINDER MOTOR OF THE "L."
Head Type in Which the Exhaust and Inlet Valves are Both on the Same Side of Cylinders.

also possible to obtain better mechanical balance with the reciprocating parts since the movement of the parts of one cylinder can be made nearly equal and opposite to the movement of the parts in the others.

A six cylinder motor has three power impulses per revolution, while an eight cylinder motor has four, thus the eight has a 33 per cent more uniform drive or torque than a six. Because of this continuous application of driving effort the machine can be throttled down very low on high gear and will accelerate rapidly even on steep hills.

Assuming that the most active part of the working or impulse stroke lasts 75 per cent of the entire stroke, it will be seen that there are at all times two very active cylinders at work on the crankshaft. For this reason a very light fly-wheel can be used as it has to store very little power.

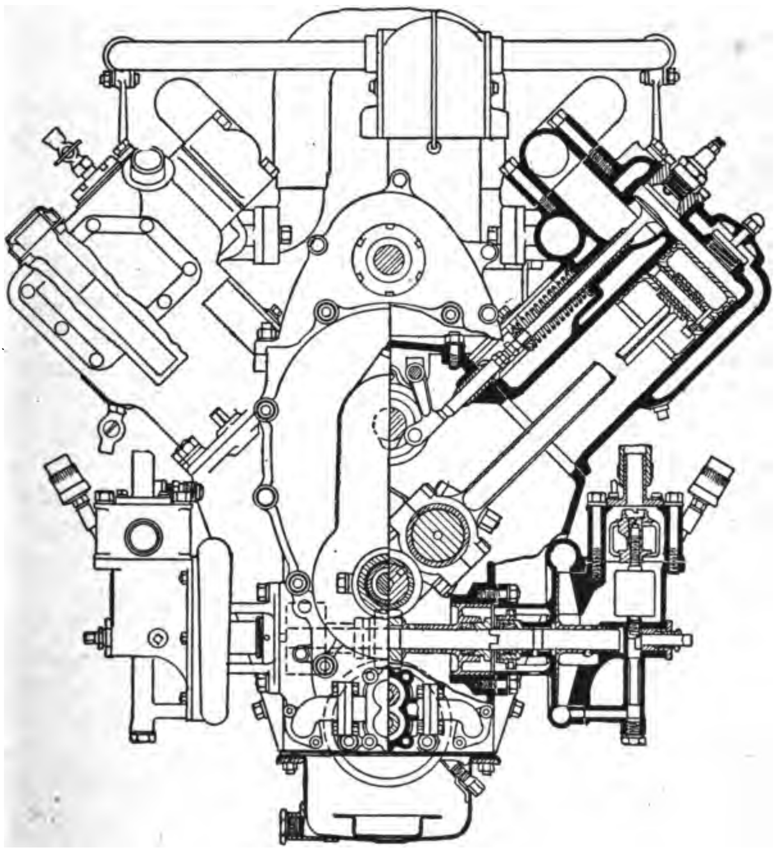
With this uniform drive always at command there is very little necessity for changing gears when threading through the traffic of crowded city streets or in climbing grades. The speed variation is from about 75 revolutions per minute to 3,000, obtained entirely by throttle. With the Cadillac this corresponds to a speed range of 2½ to 60 miles per hour without touching the gear shift lever.

As there are only four cylinders in a row, the length of the eight is the same as the four and about 25 per cent less than the six, with equal bores. Since there are more cylinders, the bore is less for equal power, which brings the length still less in comparison. A decrease in length permits either a shorter wheelbase or more body room for the passengers with an equal wheelbase. Again, the crankshaft is shorter than the six, making it possible to run successfully with two end bearings and still retain a small shaft diameter that is free from the disturbances that occur in long, limber crankshafts.

The crank-throws being all in the same plane, an eight cylinder crankshaft is as easy to machine as that of a four, and is far cheaper than the shaft of a six. A short camshaft is particularly desirable as it is free from the torsional deflec-

tions of a long shaft which causes relative changes in the firing order.

While the cylinder blocks of an eight cylinder motor weigh about 15 per cent more than a six en bloc, this weight is more than offset by the reduction in length of the two heaviest



TYPICAL EIGHT CYLINDER MOTOR (FRONT VIEW).
Each Cylinder Block is Inclined at 45 Degrees with Vertical Center Line and Contains Four Cylinders.

items, the crank-case and crankshaft. A six cylinder crank-case is very expensive as it is long and requires much metal for stiffness.

All of the reciprocating parts are light, a most important feature, since reciprocating forces add weight doubly through their inertia, causing stresses in the frame that must be resisted by increasing the metal. The small, light valves cause very little wear.

The cylinder of the eight being of small bore presents more radiating surface per unit cylinder volume than with a large cylinder, thus causing a greater loss of heat to the water jacket. This is overcome by the fact that a higher compression pressure can be carried with a small cylinder which makes the eight equal, if not superior, to the six in efficiency.

Cadillac Eight Cylinder Car.

The Cadillac eight cylinder motor has a bore and stroke of 3⅛x5⅛ inches, giving an S. A. E. rated horsepower of 31.28, the total piston displacement being 314 cubic inches.

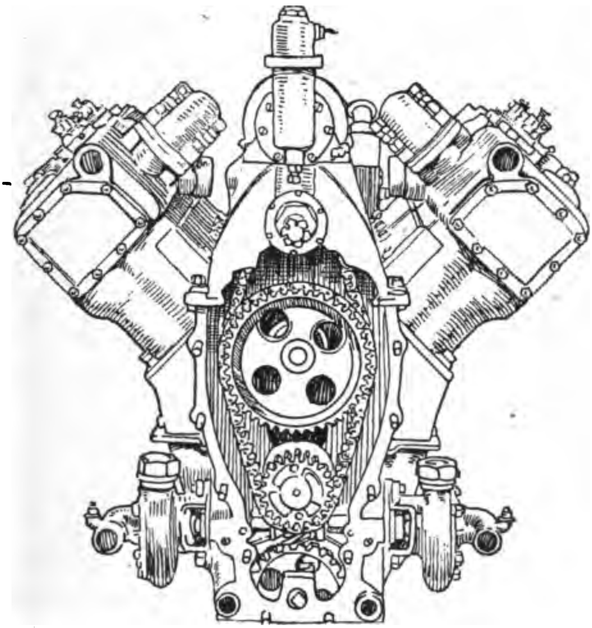
It is of the "V" type having two blocks of four cylinders inclined at an angle of 90 degrees with one another. As the two blocks are directly opposite the total length of the engine is no greater than that of a four cylinder of equal bore. Both blocks act on a four-throw crankshaft which is identical in construction to a four cylinder three-bearing shaft, this being a much simpler manufacturing proposition than the six cylinder shaft and in addition is fully one-third lighter.

Externally the cylinder blocks are similar in appearance to the ordinary en bloc four, and are fastened to the aluminum crank-case in the same way. The cylinders are of the "L" head type, the valves receiving their motion from a single camshaft located in the top of the crank-case midway between the two blocks. Two independent exhaust pipes, one from each block, lead to the extreme end of the car and are connected at the motor end to an integrally cast manifold.

As the cylinders of the two blocks are directly opposite, and as opposite cylinders act on the same crank throw, it is evident that the connecting rods must be of special construction. To meet this awkward problem one of the rods is of a clevis form, the opposing rod coming between the jaws of the clevis.

The bronze crank pin bushing is fastened rigidly to the jaws while the other connecting rod slides freely on the outside of the bushing, the outside and inside of the bushing both providing bearing surfaces for the crank pin and connecting rod.

A single camshaft is located directly above the crankshaft and is provided with eight integral cams, four of which are wide faced so as to receive the rollers of four rocker arms.



EIGHT CYLINDER CADILLAC MOTOR.

One cam operates two inlet valves or exhaust valves, as the case may be.

Directly above the camshaft is the shaft used for the Delco self-starting motor generator and which also carries the fan. This is driven by a silent chain from the double sprocket on the camshaft. A tire pump is driven by a gear that can be meshed at will with a gear mounted on the generator shaft, the pump being above and to the front of the generator.

At the front and below the crankshaft is a transverse shaft driven by spiral gears which carries a circulating pump at either end, one pump for each block. A third spiral meshing with the water pump gear drives the oil pump.

Probably one of the most interesting features of the water circulating system, aside from the double pump system, is the thermostatic circulation control with which the circulating water is kept at a constant temperature. A thermostat, consisting of a tube filled with a volatile liquid, is placed in the water pump line. This controls the water by means of a valve. When the water is too warm the thermostat expands, opens the valve and allows more water to pass through the radiator. A by-pass connected with this system also connects with the water-jacket of the carbureter in such a way that when the water is cold and the valve closed, the water will pass through the carbureter. When starting with the valve closed all of the water passes through the carbureter and none through the radiator, thus giving the carbureter the first chance at the warm water. In this way there is only a small amount of water circulating at the start which causes rapid heating of the cylinders and carbureter. When the temperature is built up to the required degree, the valve opens and a certain amount passes to the radiator.

Oil is supplied by a gear pump to a reservoir pipe running inside of the crank case from which there is a lead to each main bearing. The oil is forced from the main bearings to the connecting rod ends through holes drilled in the pins. From a connection in the reservoir pipe the oil enters a relief valve which maintains a constant oil pressure. The pistons are lubricated by splash.

A Delco unit is used for self-starting, lighting and ignition, the eight cylinder high tension distributer being built in a unit with the motor generator.

CHAPTER III

ANALYSIS OF MOTOR PARTS AND THE COOLING SYSTEM

Connecting Rod Bearings.

Near the closed end of the piston is mounted a spindle, the gudgeon or piston pin. The upper end of the connecting rod rocks on this pin, and it is important that the pin itself should not move, and that the means for fixing it should not get loose and drop away, or considerable damage may be done. It is not within our scope to detail all the devices that have been employed, but one of the simplest is to form one of the piston ring grooves coincident with the ends of the gudgeon pin which extends right through the walls of the piston. As the piston and connecting rod, being reciprocating parts, are subject to innumerable and sudden reversals of their direction of motion, they should be made as light as possible, consistently with being strong enough to withstand the explosions and convert the impulses into a rotary motion of the crankshaft. The gudgeon pin end of the connecting rod is called the small end, and the other the big end. The journals, or bearings, at the big end are adjustable, so that wear may be taken up from time to time.

The Crank Case.

The crankshaft is mounted in bearings in a casing called the crank case. The case is usually made of aluminum alloy for lightness; and, with bracket extensions, it forms a means of attaching the engine to the frame of the car; it also serves as an oilbath, into which the cranks dip as they rotate and splash the oil about so that a quantity falls into little ducts which lead to the bearings. The crank case should be made with handholes, through which the big end bearings may be adjusted; if they are large enough to allow of withdrawing the piston, so much

the better. Another arrangement is to divide the crank case horizontally, and fix the crankshaft bearings to the upper part of the case. This allows of the lower portion of the case being detached without disturbing anything else, and when this part is removed, those above it can be dealt with as may be required. A combination of the two plans is best; as the second one entails a lot of upside-down working.

Where the crankshaft has more than two cranks, there should be a bearing on each side of each pair of cranks, otherwise there is a danger of the crankshaft bending, and even breaking, under its work.

Function of the Half-speed Shaft.

As each operation of the motor happens only once in two revolutions of the crankshaft, the firing of the charge and the opening of the exhaust valve are controlled by a shaft rotated at half the speed of the crankshaft. For this purpose gear wheels are fixed to the crankshaft and to the "half-speed shaft"; these wheels gear together, and the wheel on the half-speed shaft has twice as many teeth as the wheel on the crankshaft. On the half-speed shaft is fixed a cam, that is, a ring or collar bearing a hump or projection on its periphery. On this cam stands a rod or plunger, and this plunger is in line with the stem of the exhaust valve. Hence, at every revolution of the half-speed shaft (and so at every alternate revolution of the crankshaft), the cam comes round and lifts the exhaust valve, through the plunger.

The Exhaust Valve.

It should be pointed out that the term valve is used to express both a whole and a part. In the larger sense the "valve" means both the door and its frame—the disk and its seating; in its smaller sense it means the door or disk only. From the form of the disk, and the stem under the disk, this type of valve is called a mushroom valve. Owing to the length of the stem used in motors, the valve looks perhaps more like a flat-headed nail than a mushroom. The seating forms a shoulder in a passage communicating with the combustion chamber on the

one hand and the exhaust pipe on the other. Sometimes the exhaust valve is arranged directly over the combustion space in the cylinder head, but more often it is arranged in an exhaust valve box at the side of the cylinder. The upper part of the stem works in a guide, and a plate or washer is mounted on the lower part of the stem. Between the guide and the washer there is a strong spring, which normally holds the valve tight down on its seating. The edge of the valve and the seating are generally beveled, and carefully ground to the same angle, so that the valve may be gastight when closed.

It will be remembered that the exhaust valve is only open during one of the return strokes of the piston. This corresponds to half a turn of the crankshaft, and to a quarter of a turn of the half-speed shaft. Hence the hump only occupies about a quarter of the periphery of the cam. In practice, it is found best to allow the exhaust valve to open before the piston has quite finished its driving stroke, and to close exactly at the top of the return stroke. The valve should open fully and close completely as promptly as possible, but each end of the hump must be inclined—the forward end to lift the valve plunger in ordinary running, the rearward end to do the same in case the engine is accidentally reversed. Were it not for this last consideration, the hump might have a radial or precipitous end. Sometimes a hinged arm is interposed between the surface of the cam and the foot of the plunger; this is useful in overcoming the transverse action set up by the inclines when operating directly on the plunger, and (when an adjustable arm is used) in providing means for controlling the motor by varying the lift of the valve. The exhaust passage or port, the valve itself, and the exhaust pipe should be of ample dimensions, so that the exhaust gases may be cleared out with as little resistance as possible. A good many motors are now constructed with a large chamber, into which the exhaust ports of all the cylinders open. This provides for more ready expansion of the gases than if they are led directly into the more or less restricted exhaust pipe.

When the cylinders of the engine are separate castings, the

branches of the exhaust pipe should be connected in such a way as to allow for a slight relative movement due to unequal expansion of the cylinders.

Silencing the Exhaust.

The object of the exhaust box is to silence or muffle the noise of the exhaust. At the same time it must allow of the ultimate egress of the gases as freely as possible, otherwise it will set up a back pressure, which will reduce the effective power of the engine. In the box are a number of tubes or plates, which turn the stream of exhaust gases first one way and then another, as in a maze, allowing them all the time to expand more and more, and ultimately allowing them to pass out through a number of fine holes or a pipe. These holes, or the pipe, should not point directly toward the ground; if they do, the exhaust will greatly augment the dust raised; and if they point backward it is very unpleasant for anyone behind, during a block in traffic. The box should be of good dimensions; and should be carried under the back part of the car, so that the occupants may not be troubled by any fumes emitted by it. Do not forget that the exhaust pipe and box get extremely hot, and nothing liable to be damaged by heat (fingers, tires, eatables, etc.) should be brought near them.

The Inlet Valve.

The inlet valve may be opened either by the suction of the piston, or positively like the exhaust valve. In the former case no special mechanism is required; the valve is made very light, and is normally held closed by a comparatively weak spring. Some prefer the automatic valve for high-speed work, and it is certainly simpler than the mechanically-operated valve. Where the latter form is employed, it is operated by a cam on a half-speed shaft like the exhaust valve. In fact, the valve parts can be made duplicates of each other, thus reducing the number of spare parts that should be carried. The contention that an engine with mechanically-operated inlet valves can be run slower than one with automatic inlet valves is to some extent supported by practice; any way, the former

are more often used than the latter. But, however the valve is operated, the charge is drawn into the cylinder by the so-called suction of the piston.

The inlet valve is arranged in the port or passage connecting the inlet pipe with the combustion space. When it is located in the cylinder head, and is mechanically operated, the stem is directed upwards, and is operated on by one end of a rocking or see-saw arm, the other end of the arm being actuated by a long plunger rod. More often, however, the inlet valve is set head upward, like the exhaust valve, and is worked by a cam and short plunger. The inlet valves with their boxes may be arranged on the same side of the cylinders as the exhaust valves, in which case they are all operated from cams on a single shaft. This keeps down the number of parts, but crowds them together rather, and generally involves a long and tortuous inlet pipe, in addition to a tendency to unduly heat and therefore rarefy the induced charge. If the inlet valves are arranged on the other side of the cylinders, a second half-speed gear and shaft are necessary, but the various parts are rendered more easily accessible, and the timing of the exhaust and inlet valves can be regulated independently. This timing is a very important matter, as, unless the valves open and close just at the right times, the engine will not give off its full power. The close fitting of the valve head on to its seating is also important, and to facilitate the grinding-in of the valve, the head should be provided with a screwdriver slot. If the valve seatings are detachable, the grinding-in process can be conducted away from the rest of the engine, and the risk of the abrasive material finding its way into the cylinder is avoided.

The inlet and exhaust ports should be short, and, generally, the combustion space should be as free from pockets as possible, as these tend to retain portions of the exhaust gases which mingle with, and deteriorate, the incoming charges of combustible gas. Externally, also, the motor should present a clean appearance, and all fixings should be well secured and readily accessible

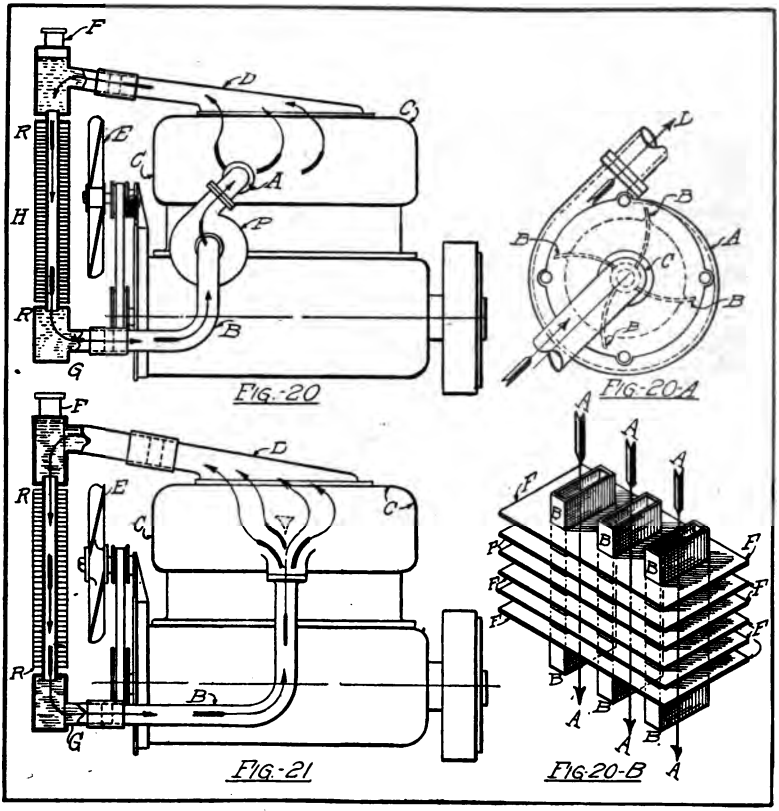
Cooling System.

Owing to the intense heat generated by the explosions in the cylinders it is necessary to cool the cylinder walls in order to hold lubricating oil on the interior surfaces. As the temperature of the burning gases is in the order of 3,000 degrees and the vaporizing point of the oil is generally less than 600, it is evident that a great amount of heat must be removed. Unfortunately the necessity of cooling the walls considerably reduces the efficiency of the engine, for in the average case from 25 to 30 per cent of the heat generated by the fuel is wasted in the water jacket. The function of the cooling system is therefore not to keep the cylinders cold but to keep them cool enough so that we can maintain an oil film on the surfaces of the bore. At present, the temperature is entirely dependent on the vaporizing temperature of the lubricant.

Cooling can be performed either by placing radiating ribs around the cylinders to increase the radiating surface or by surrounding the cylinders by a water jacket. When cooling by air it is difficult to obtain enough effective cooling surface with the ribs, especially with large cylinders, and for that reason there is but one automobile manufacturer that builds air cooled motors as a standard. With rib cooling a strong current of cold air must be constantly maintained by a fan.

Merely holding the water in the jackets would not keep the cylinders cool for long, so we must either allow a stream of cold water to run continuously through the jackets or circulate the water through a cooler where the heat may be dissipated. In the automobile the water is cooled, after passing out of the water jackets, by means of what is known as a "Radiator." The water in passing through the radiator is split up by a number of small tubes, which having a large surface in proportion to their contents, rapidly radiate the heat from their surfaces to the outside air. A pump, usually of the centrifugal type, forces the water from the jackets into the radiator.

By adding radiating fins to the tubes and by placing the radiator in front of the automobile where it will catch the wind, it is possible to remove the heat rapidly enough to keep the cylinders at any desired temperature. The radiator acts simply as an extended surface of the cylinder walls. To aid



COOLING SYSTEMS.

the cooling and to keep the motor cool, when the car is standing idle with the motor running, it is necessary to install a small fan just back of, and inside of the hood. This is shown by the accompanying figure. The fan may be either driven from the motor by a belt or gear, although the most common practice is to belt it to the crankshaft.

In Fig. 20 is shown a system of the type described, in which C is the water jacket of the cylinders, P is the pump, R is the radiator, and E is the fan. The pump draws the water from the radiator at the bottom, G, through the pipe B and forces it into the jacket at A. It now passes through the jacket as shown by the arrows and returns to the radiator through the upper water manifold D. This circulation aided by the radiator keeps the cylinders cool. The wind caused by the motion of the car, shown by arrows H, passes through the radiator, the force of the wind being assisted by the fan E. The system is filled with water through the radiator filler Cap F. The air in passing through the radiator flows over the engine cylinders which still further reduces the temperature.

A typical centrifugal pump is shown by Fig. 20A in which A is the outer casing and B is the propeller wheel. Water enters at the side and in the center of the casing at C, and on coming into contact with the wheel is thrown outwardly against the casing by centrifugal force. This force caused by the rotation of the water forces the water out at D with considerable pressure. The shaft from the wheel is generally driven from the camshaft gears or from the camshaft.

A section of a tubular radiator is shown by Fig. 20-b in which B-B-B are the tubes through which the water passes in thin sheets in the direction of the arrows A-A-A. The radiating surface is increased by the fins F which are soldered to the tube. There are many radiators, widely different in the arrangement of the tubes, but this is a simple type that is extensively used and will serve as a guide to other constructions. Theoretically, the thinner the sheet of water in the tube, the more efficient will be the radiator, but practical reasons limit the thinness, the principal one being that sediment and scale would soon clog a passage smaller than 1/8 inch.

Thermo-Syphon System.

To supply the circulating system, and to obtain what is in some respects a better heat distribution, it has been the

practice with several prominent makers to discard the pump and to depend on the natural circulation. This circulation, which is due to the difference in temperature between the top and bottom of the radiator is known as the "Thermo-Syphon System," and depends for its operation on the fact that warm expanded water is displaced by the heavier colder water in the radiator. Fig. 21 shows thermo-syphon circulation. The water in radiator R becomes cooled and therefore heavier than the warm water in cylinder jacket C, in the manifold D, or in the top of the radiator, and its weight therefore forces the warm water up and into the upper part of the radiator. This water becomes cooled, and the action continues. For successful thermo circulation, the pipes D and B must be very large in diameter, and all passages free and easy to reduce the friction. As the pressure causing the water to flow is very slight when compared with a circulating pump the greatest care must be taken to eliminate friction.

The thermo-syphon system has the advantage that the rate of circulation is in proportion to the heat and not to the engine speed as in the case of the pump. When the engine is running slow and laboring hard, the heat is at a maximum, but with the pump system the circulation is deficient as the pump is also running slow. When the circulation depends only on the heat, as with the thermo system, the cooling and circulation are the most rapid when the engine is hottest.

CHAPTER IV

MOTOR TRUCKS—GASOLINE AND ELECTRIC

In principle the gasoline motor truck and pleasure car are very similar, any difference between the two lying in the arrangement of the smaller details and in the size of the weight bearing members. In fact many of the most successful light delivery vehicles are built on a chassis nearly identical with the pleasure car chassis turned out by that particular firm. With the heavier trucks, such as the 3 to 5 ton types, the low speeds and heavy loading demand changes in the final drive, in the type of tires, method of control, style of wheels and in the weight of the motor. Every gasoline motor truck has the following elements in common with the pleasure car:

Gasoline Motor (usually four cycle), with carbureter, magneto, muffler, etc.
Clutch, for giving free engine.
Change Gear or Transmission.
Differential—Radiator—Throttle Control.

The motor is usually heavier than one with equivalent power in a pleasure car, and develops its rated horsepower at a much lower speed, which power for power means a larger bore and stroke. The low speed motor is the result of the low road wheel speed used with the truck except in cases where worm drive is used. In the majority of cases, the motor is provided with an automatic governor which limits the speed of the vehicle in such a way that the driver cannot force the machine above a certain maximum fixed by either the maker or owner. This appliance is required by ordinance in many cities.

The ignition may be by any system commonly used by the

pleasure car, but with the difference that the spark is either fixed, or automatically advanced and retarded by mechanism within the system. This arrangement takes the spark adjustment out of the hands of the driver, thus giving him less to attend to and also increases the efficiency of the power plant. The advance and retard handled by a careless driver will add enormously to the fuel consumption and total cost of service.

Motor truck transmissions may either be of the planetary or sliding type, with the same latitude in the design of the clutch. In several cases the power of the engine is transmitted to the rear wheels electrically through a generator connected with the engine and electric motors attached to the wheels, the trucks of the four-wheel drive type having a motor applied to the front as well as to the rear wheels. There are also several examples of hydraulic transmission in which the power is transmitted to the rear axle by engine-driven pumps and hydraulic motors. Friction drive is not as frequently used as the above mentioned types.

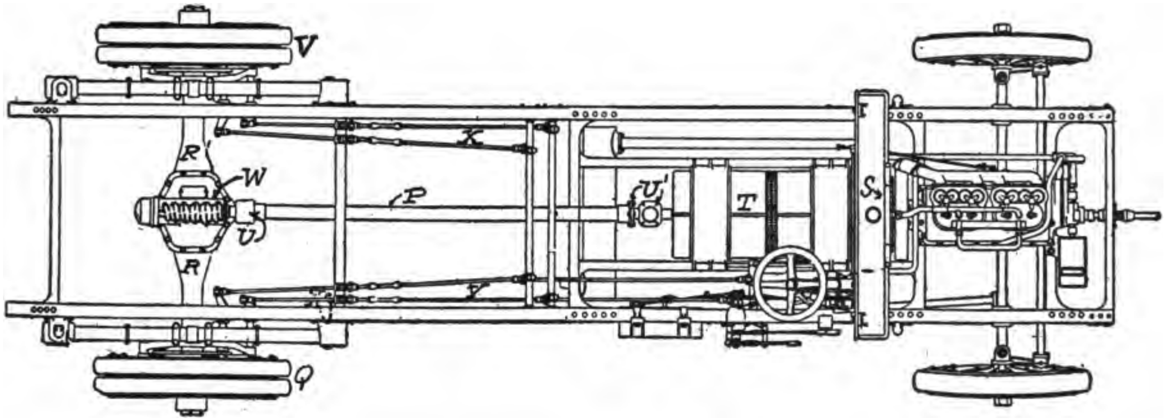
Owing to the great importance of tractive effort on a large truck, it is not uncommon to find well developed examples of four-wheel drives or "couple gears," in which all wheels are equally driven. These trucks are generally either of the electric or hydraulic transmission type owing to the difficulties experienced in mechanically connecting the power with the swiveled front wheels. In any case, the complication of the four-wheel drive is so great as to exclude it from any but the heaviest trucks. Four-wheel drive gives increased hill climbing ability, stability on slippery pavements, and an increase in towing power.

The greatest point of difference between trucks and pleasure cars generally lies in the manner by which the power is transmitted from the transmission gears to the rear wheels, this difference being particularly evident in the larger trucks. While a bevel gear driven, live rear axle is used in both pleasure and light delivery cars, the low speed of the large rear wheels in heavy trucks together with the great speed reduction demands a different system. This must be such that the

reduction between engine and road wheel speed is much greater than with the pleasure car, it must be capable of withstanding the enormous shocks produced by driving over rough roads, and must if possible prevent the transmission of road shocks to the delicate parts of the engine, gearing and axle. In addition, the truck system must be capable of withstanding the heavy stresses due to the increased torque and pull at low speeds stresses that are much heavier than those encountered with the high speed pleasure car. It should be noted here that the pull or twist on any part increases in direct proportion to the decrease in speed with equal power, so that with half speed the stresses are twice as great as those at full speed with equal transmission of power. This if course neglects stresses due to vibration and windage that increases as the square of the speed.

As explained in the first chapter, the rear axle of the propeller shaft-driven car is split, one-half of the shaft being connected to one wheel and one-half to the other. One-half the differential gear is connected to each half shaft, the complete unit being installed in the axle tube. This of course produces a weak, complicated rear axle system and necessitates placing the delicate differential gears where they are subjected to the full force of the road shocks, a condition permissible on light cars and delivery wagons but not particularly desirable for heavy trucks.

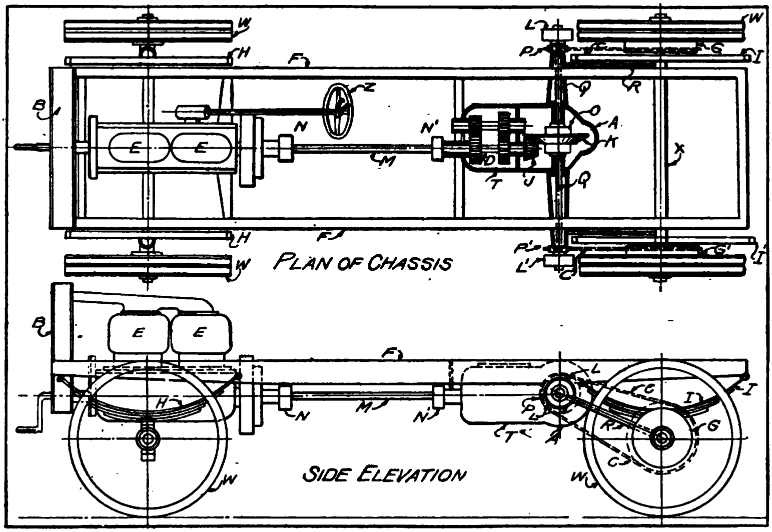
By using a chain drive it is possible to incorporate the differential in the transmission housing and to place the combined unit on the frame where it is protected from road shocks by the intervention of the springs. This also permits the use of strong, solid, one-piece rear axle of simple construction with high road clearance. The chain protects the engine and drive mechanism from excessive road shocks by reason of its flexibility, that is, it protects these parts from the torsional shocks due to suddenly checking the rotation of the road wheels. When protected from dirt by a casing, the chain drive is reliable and noiseless; or at least as noiseless as it is necessary with a truck.



WORM DRIVEN MOTOR TRUCK.

In this cut the Worm W, driven through the Propeller Shaft P, acts on a worm wheel connected with the Shafts R-R'. The Worm Wheel contains the Differential Gear. The Divided Shafts R-R', drive the Wheels Q-V, respectively. Changes in the Gear Ratio are made in the Transmission Box T, from which the power passes through the Universal Joints U and V, and the Propeller Shaft P, to the Rear Axle. Letters X and L, designate the Brake Rods. The Radiator S is of the "Renault" type and is placed at the rear of the engine.

Worm drive may either be placed directly on the rear axle in place of the usual bevel shaft drive or may be used in connection with a chain drive. The worm gear is efficient and is capable of a great speed reduction without much reduction in the road clearance. The twist in the axle tube of the worm gear caused by the power or by braking is resisted either by a torque tube or radius rod as in the bevel driven axle or by the



CHASSIS OF GASOLINE TRUCK.

action of the springs, an arrangement known as the "Hotchkiss" drive. By the latter method the rear semi-elliptic springs carry both the weight of the vehicle and the torsion of the axle. Both systems are extensively used and at present it is difficult to say which presents the most advantages.

A typical chain driven truck is shown by Fig. 1 in which the engine E is mounted in the chassis frame F, a sliding transmission T being connected to the engine through the shaft M. A pinion J drives the main bevel K in which the differential O is installed, a shaft Q running from the differen-

tial to the two chains P and P^1. This mechanism is covered by the housing A. Two brakes L and L^1 are mounted on the end of the drive shaft Q. From the sprockets P and P^1 run two chains C and C^1 to the main sprockets G and G^1 fastened to the wheels W and W^1. Brake drums are mounted on the interior of the sprockets. The weight is carried by the springs H and I at front and rear. As both wheels turn freely on the shaft it is possible by this arrangement to have a solid bar rear axle X. The radiator R is in the usual place, both the engine and radiator being covered by a hood or by the footboard, depending on the body design. The pedals and brake controls are the same as on the usual pleasure car, that is a change gear lever, pedal brake, emergency brake and throttle. The steering wheel is indicated by Z.

Except on the lightest express and delivery cars, the tires are solid owing to the fact that vibration is not of as much importance on the truck as reliability and the ability to stand up under heavy loads. Depending on the size of the truck, there may be one or two separate sets of solid tires mounted on each wheel.

Electric Trucks.

On short hauls and under proper road conditions the electric truck is more economical than the gasolene, especially if the loads are light and if there are many stops to be made. For long, fast hauls it cannot compete with the gasolene machine. Each has its individual field of usefulness.

Mechanically, the electric truck proper is very simple, consisting as it does of an electric motor, storage battery, reduction gear, and controller. Unfortunately this is not all of the apparatus necessary for its operation since there are a number of devices used in the charging that do not appear on the car, some of which are expensive in both first cost and in operation. The most expensive part of the electric, the battery, deteriorates rapidly unless properly cared for, the mileage per charge is low, and the owner is always at the mercy of

the local electric light company unless he goes to the further expense of installing a generating system.

Except in the arrangement of the gear used for reducing the high speed of the motor to that of the road wheels there is not a great diversity of design possible with an electric truck. The motor may be mounted on the rear axle and drive through planetary reduction gears in the wheels, or the motor may drive through chains or a worm as in the case of the gas car. Worm drive is popular with electric pleasure vehicles, while combinations of gears and chains may be used for the trucks. It should be remembered that the speed of an electric motor is much higher than that of a gasolene motor, and as the road speeds are generally lower with the electric there is a necessity of greater reduction in the gearing. In some cases, two electric motors are used, one for each wheel, so that no differential is required. To prevent a great reduction in the final drive it is common practice to have an intermediate gear in the housing of the motor, on the countershaft principle.

Either lead or Edison batteries may be used, the former being the most efficient and generally the more desirable, while the latter are lighter and not as easily damaged by careless handling or neglect. Often the latter condition more than overbalances the efficiency of the lead cell, especially when overhead is considered. The voltage of the Edison cell is lower, and the bulk of the cells for a given voltage is greater than the lead type, but the total weight is lower, and they may be totally discharged without damage. Lead cells require continual attention and cannot be left in a discharged condition without damage, but possess the ability to temporarily "come back" after the discharge has been carried below normal. The voltage fluctuation is comparatively small between full charge and normal discharge. The voltage, per cell, of the lead battery is 2.6 volts at full charge and that of the Edison battery 1.4 approximately, thus demanding more Edison than lead batteries in series for a given voltage.

The lead cell consists of two or more plates immersed in a dilute solution of sulphuric acid, the surfaces of the plates

being covered with a paste of lead salts known as the "active material." The composition of the active material on the positive plate varies from that on the negative owing to the action of the charging current. The acid acting on the active material in changing its chemical composition produces the "secondary" or discharge current of the cell. Current is produced until the material is entirely decomposed by the acid. During the discharging process the density of the acid also changes, the specific gravity varying from 1,300 at full charge to 1,150 in the fully discharged condition.

When exhausted, the cells are recharged by passing current through the plates and acid in the opposite direction to that produced during the discharge. This requires direct current and must be maintained at a rate depending on the make and size of cell. It is one of the serious drawbacks to the electric vehicle that the charging process takes so long a time, and that it must be repeated so frequently. Owing to the evaporation of the battery solution it gradually becomes more dense so that it must be tested occasionally and reduced if necessary.

As it is impossible to charge a battery directly from an alternating current main and as the majority of lighting circuits at the present time deliver alternating current, it is necessary to use a rectifier in such a circuit when charging. A rectifier is an appliance used for converting an alternating current into direct, or for straightening out the continually reversing alternating waves so that they will flow through the battery in constant direction. Another device known as a "converter" performs the same function, and is used principally in cases where a number of vehicles are to be charged at the same time. When direct current is furnished by the electric light mains it is only necessary to install a rheostat for the control of current strength.

The Electric Motor.

The motor used with the electric truck is of what is known as the series type in which the field circuit and armature are

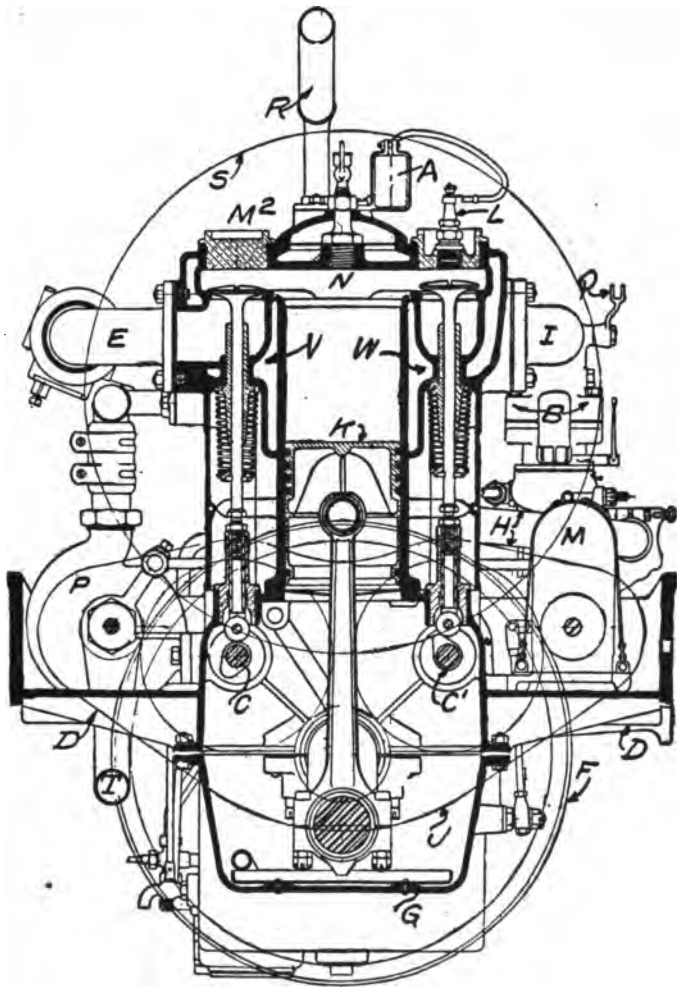
connected in series. This gives the most powerful pull or starting torque and is of the type generally used in electric street cars, although much smaller.

The Control System.

In regard to control, the electric truck is much simpler to handle and gives a wider variation of speeds by a single lever than the gasolene machine, there being but a single control lever and a brake. The control lever corresponds roughly to the control lever on an electric street car, inasmuch as its action is to control the flow of the current through the motor. It varies the voltage at the motor from a few volts to the full voltage of the battery, usually from 60 to 80 volts and as the speed of the motor is roughly proportional to the voltage, other conditions being equal, it therefore varies the speed. When on a hill or incline, the increase of speed due to a given voltage is not as great as when on the level owing to the fact that the motor must be slowed down to allow more current to flow and thus meet the demands for the increased power necessary for climbing the hill.

The voltage variation is met in two of three possible combinations, or in the case with two motors is accomplished by all three. The first and a seldom used method is by using a variable amount of resistance in series with the motor and battery, the amount of resistance being determined by the position of the controller handle, all batteries being at all times in circuit. This method is very wasteful, since the energy due to the drop in voltage is all converted into useless heat.

A second method used in all single motor vehicles is known as the "Series-Parallel" control in which very little resistance is used, and this only on intermediate control steps. By this method the battery arrangement is varied by the controller so that more or less cells are connected in series, thus varying



A—Ignition Cable Support
B—Carbureter
C—Exhaust Camshaft
C1—Intake Camshaft
D—Supporting Arms
E—Exhaust Manifold
F—Fly-Wheel (Rear)
G—Lower Half of Crank-Case
H—Water Manifold
I—Gas Intake Manifold
J—Silent Chain Magneto Drive
K—Piston
L—Spark Plug
M—Magneto
M2—Valve Plug
N—Combustion Chamber
P—Water Pump
Q—Throttle
R—Water to Radiator
S—Fan Front

the voltage at the motor. As the steps between the different possible combinations of cells would differ too greatly in voltage, a very small resistance is introduced in the intermediate steps so that the truck will build up speed smoothly instead of by a series of jerks. For illustration, but not as an example of any particular case, we will assume that our battery voltage is 60 with all 30 cells in series for top speed, and that the voltage of each individual cell is 2 volts. The arrangement of the steps may be as follows, each step being represented by a distinct controller position:

Step 1—First Speed—Required 10 Volts at Motor. This will call for 5 cells in series (2 volts per cell). As we must have 30 cells for our maximum of 60 volts, we will connect with the controller so that there will be 6 sets in multiple, thus giving a series-multiple combination. As a multiple combination gives a greater volume of current than if we used a single set of 5 cells, we have met our starting condition.

Step 2—Second Speed—Required 18 Volts at Motor. This voltage cannot be met exactly by any one combination of 30 cells, since we will require 9 cells in series and this is not contained equally into 30 for the multiple connection. We will therefore be compelled to adopt the next higher equal combination and cut down the higher voltage obtained by a resistance. Ten cells in series will give 20 volts, and as 10 is contained into 30 three times, we will have 3 groups of 10 cells in series. The difference between 20 and 18 volts must be cut down by resistance. As even this small resistance is wasteful we must endeavor not to run for any length of time on Step 2.

Step 3—Third Speed—Required 24 Volts at Motor. This will require 12 cells in series, but this is also impossible as a direct speed as 12 is not contained equally into 30. We must take the next higher combination with resistance as before. At 30 volts we will require 15 cells in series with enough resistance to cut this down to 24 volts.

Step 4—Fourth Speed—Required 30 Volts at Motor. This is an even speed, as with 30 volts we will need 15 cells, and 15 is contained equally in 30. As we already have 15 cells in series it will only be necessary for the controller to cut out the resistance without changing the cell connections.

Step 5—Fifth Speed—Required 36 Volts at Motor. This will require resistance. Remaining intermediate steps as before —using resistance, etc.

Top Speed—Required 60 Volts at Motor. All cells are in series with full battery voltage at 60 volts.

The motor voltages specified above are those supposed to be found necessary for a uniform increase in the speed. These are generally first determined by experiment with a given type of truck for the reason that the road resistance, etc., of every truck type varies throughout the speed range at a different rate. Because of the waste energy, continuous running should not be done on the resistance speeds.

In running, the brake should not be applied until the controller is in the off position and with the motor completely out of circuit, for this would produce a heavy and injurious draft of current from the battery. Many controllers are interlocked with the brake system in such a way that either the movement of the brake lever will open the motor circuit, or the brake system will be operated directly by the controller lever itself.

A voltmeter and ammeter, and sometimes a wattmeter, are placed on the dash so that the condition of the batteries and amount of current drawn can be readily determined. The wattmeter measures the total amount of power consumed or supplied to the vehicle (watts = volts $\times$ amperes), so that the owner can compute the cost per ton mile of the goods delivered. The tonnage is of course determined by the scale-yard while the mileage is determined by the speedometer, and by properly kept records of these quantities it is possible to regulate the traffic so that the expenses can be kept at the lowest point.

Truck Governors.

At the present time nearly every gasolene truck is provided with some form of governing device for keeping the speed of the machine under certain limits. This device is installed to prevent overspeeding and misuse by the drivers and for this reason is an important factor in prolonging the life of the car. In some localities there are ordinances, that have been passed or are under consideration, that require a governor on every commercial vehicle.

So destructive are the results of overspeeding a heavy truck that many truck builders, who are bound under a guarantee contract, send inspectors periodically to determine whether there has been any tampering with the governor adjustment due to the customers' desire for "speeded up" service.

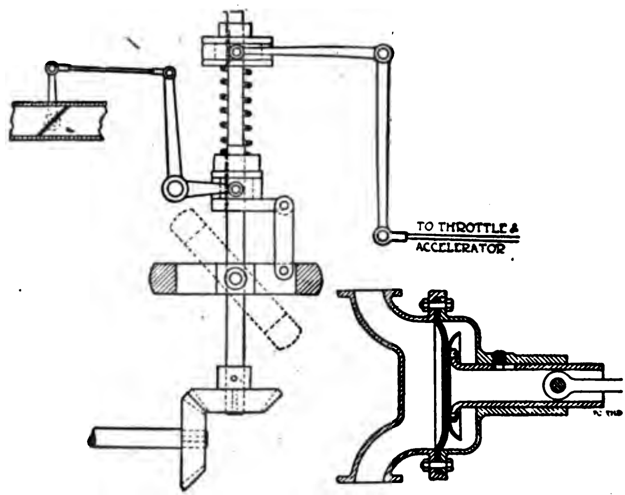
Aside from the question of abuse, a governor has a decided effect in increasing the efficiency of motor operation. Since automatic throttle control is not affected to such a degree by the jolts and jars to which a commercial vehicle is subjected, the gas flow to the engine is more uniform and the carburetor is correspondingly more efficient. In addition, the governor will hold the engine at the most efficient speed which is seldom attained through any considerable period by manual control.

In general the governors now used can be divided into three principal classes, according to their method of control: (1) Governors controlling by centrifugal force; (2) governors actuated by hydraulic pressure.

Hydraulic governors regulate through the variation in pressure of the water in the cooling system, the water acting usually on a flexible leather diaphragm, the action of which is transmitted to a regulating gas valve through a linkage or lever system. Since the pressure of the water on the diaphragm is directly proportional to the engine speed, there is a definite gas valve opening for every engine speed, the gas admission being independent of the load on the engine. This is the type used by the Packard truck.

The greater majority of governors act by utilizing the cen-

trifugal force developed by revolving pivoted weights, the weights either operating a gas valve or acting on the ignition system in a manner similar to the governor of a steam engine. In effect the governor consists of a vertical rotating shaft on which is mounted a pair of pivoted weights controlled by springs which pull them towards the shaft. As the speed of the shaft increases, the centrifugal force acting on the weights tends to pull them outward against the pull of the springs. In moving out, the weights through a lever system raise a collar



TRUCK GOVERNORS.
Centrifugal Type Governor at Left—Hydraulic Governor at Right.

which in turn closes a gas valve, cuts out the ignition, or advances and retards the spark.

Driven from the engine, the governor tends to keep a constant engine speed independent of the speed of the vehicle when on different positions of the change gears. With constant engine speed, the only variation in the vehicle speed is made by the different gear combinations in the transmission. When driven from the vehicle wheels or from the propeller shaft, the governor still acts on the gas valve or ignition sys-

tem but allows the engine speed to vary with the gear ratios in the transmission, the limit being only on the speed of the road wheels.

In either case, control by a gas valve situated between the carburetor and engine is far superior to control by advance or retard or by ignition cut-out.

Speed Control.

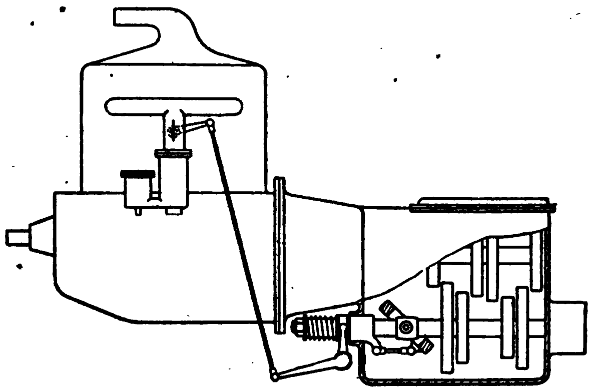
When the governor is driven directly either by centrifugal force or by hydraulic pressure and acts on a gas valve reducing the flow of the mixture when the engine exceeds a certain speed there is no power advantage in dropping into the low gear except for that due to the increased leverage of the reduction gearing. Since the engine cannot be speeded up beyond a certain speed on low the tractive effort is limited within a short range.

With a low maximum engine speed the life of the engine is increased but at the expense of the power developed by a certain size engine, thus a compromise must be made between the output and the life of the motor. To operate the motor at a low speed on high gear it is necessary to sacrifice power on the low gears at the very time when the greatest power is required. This often results in running an engine at a speed 50 per cent less than would have been possible on low speed.

According to Theodore Douglas in a paper read before the Society of Automobile Engineers, a truck only utilizes 30 per cent of the rated power output during 90 per cent of the running time. This means that the motor is throttled down to an inefficient point at practically all times in its travels, and it would seem offhand that it would be the best practice to have the gear ratio such that the engine speed would be reduced to a point more closely corresponding to the actual power required, running on full throttle, or else decrease the size of the motor.

Speed.

With the governor attached to the vehicle wheels, or what is the same thing, attached to the propeller shaft, the engine speed limit varies according to the particular transmission gear that is in mesh at any one time. This allows operation on high gear with moderate engine speeds. As the car is thrown into the lower gears, the engine speed increases to maintain the limit of vehicle speed thus increasing the pull on low as it should be, but may allow the motor to race at



GOVERNOR CONTROLLED FROM PROPELLER SHAFT.

an excessive speed on second gear and to a prohibitive speed on first and when standing still in neutral. When standing still, there is of course no limit to the engine speed with this type of governor.

In the following Mr. Douglas summarizes the characteristics of an ideal vehicle governor:

Power—This is the most important quality of a governor, and upon it, and its proper balance, will depend very largely its efficiency. To possess this quality effectively the governor must be static, that is, be a one-speed, one-position governor.

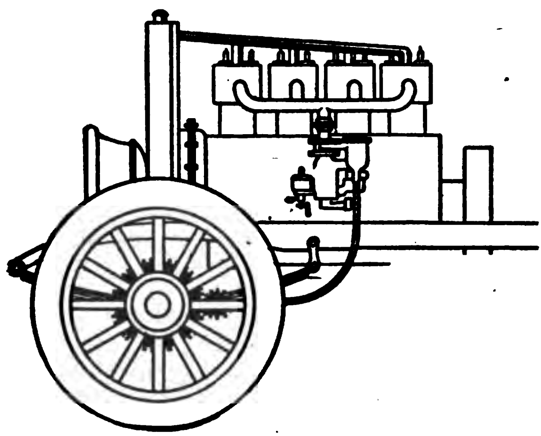
Sensitiveness—This quality is dependent on a positive increase and decrease in power between small variations of

position, and hence of speed, and the difference in speed between any two positions must be small.

Flexibility—The governor should be capable of maintaining the power output of the engine closely proportionate to the power requirement, regulating to slow engine speeds for high gear service, where low power is required, and to higher engine speed for low gears when the maximum power capacity of the engine can be effectively employed.

Delivery—This quality is dependent largely on the type of control valve employed. The governor construction should be such as to include, and to co-ordinate with, a valve of such design as to require but slight travel in effecting its extremes of position. The valve should be non-fluttering, of low resistance to the gas flow, and offer, in the automatic control of the engine, full throttle, when necessary, until practically the moment of required cutoff is reached.

Regularity—The governing influence, power and valve closure should vary proportionately as the speed; or, between the extremes of the governor range the differences in power and closure between any two required intermediate positions, should be equal.



GOVERNOR DRIVEN FROM ROAD WHEELS.

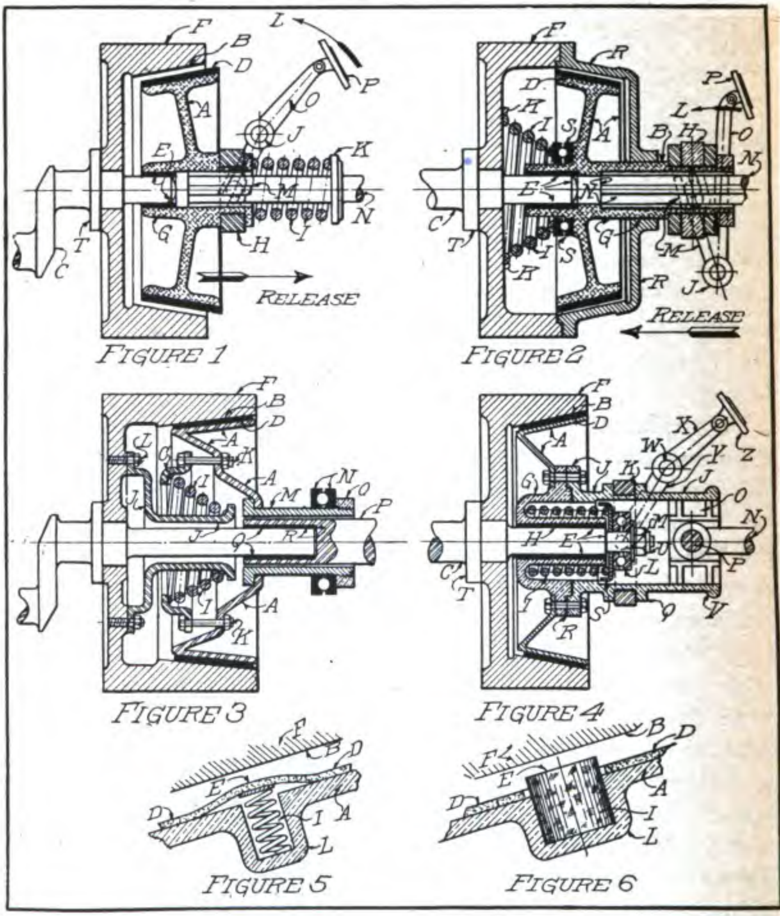
CHAPTER V

CONE AND DISC CLUTCHES

As explained in Chapter I, the clutch is for the purpose of disconnecting the engine from the driving gear of the car, this being necessary when changing gear, reversing the car, or in making short stops with the engine running. These clutches are invariably of the friction type in which the driving force is transmitted through the friction between two abutting surfaces.

While many types of friction clutches have been devised from time to time, nearly every car in the market is supplied with one of two types—either the cone or the disc clutch. The frictional surfaces may be either metal to metal, or metal to leather or fabric, the majority of cone clutches being of the latter class.

A typical cone clutch is shown by Fig. 1, in which F is the fly-wheel and C is part of the engine crank-shaft, the fly-wheel being attached to the crank-shaft by the bolted flange T. The interior of the fly-wheel is bored out with a taper face shown by B, which forms the frictional surface of the engine half of the clutch. A prolonged portion of the crank-shaft E serves to support and center the other half of the clutch. A cone A, the driven member of the clutch, has a leather covered face D turned to the same taper as the fly-wheel face B. When the cone is forced to the right by the spring I the faces



TYPICAL CONE CLUTCHES.

Fig. 1.—Simple Type of Cone Clutch.
Fig. 2.—Cone Reversed with Thrust Bearing.
Figs. 3, 4.—Cone Clutch Arranged So That There is No End Thrust.
Fig. 5.—Spring I Under Leather E Allows Easy and Gradual Engagement with Face B of the Fly-Wheel F. D is the Clutch Leather.
Fig. 6.—The Cork E Causes Easy Engagement with Fly-Wheel Face B. Leather D Comes Into Engagement After Cork is Fully Compressed.

B and D engage so that the engine drives the propeller shaft N. The driving force is due to the frictional engagement between B and D, and as the friction is proportional to the pressure of D on B, the drive is assisted by the wedging of the taper cone in the bore. The smaller this angle of taper, the greater will be the pressure between the two parts. If this angle is made too small, the clutch will be difficult to release and is likely to be "Savage" or "Fierce," that is, will take hold with a sudden jerk. In practice, with a leather faced cone, this angle is generally about 12 degrees.

The inner end of the cone hub G, turns freely on the shaft extension E which tends to center it in the bore and supports the long overhang of the shaft N. The spring I acts against the hub at the left and a shaft collar K at the right. When the clutch pedal P is depressed in the direction of the arrow L, the slotted end M of the pedal lever acts on the collar H, causing the cone to be disengaged by moving to the right. The pedal lever O turns on the spindle J, and the cone hub G is keyed to the shaft N which leads to the transmission and from there to the propeller shaft.

Since the amount of friction between B and D limits the driving power of the clutch we must not only obtain great pressure from the spring and wedge combination but we must select those materials for the faces that produce the greatest friction. Since leather on iron has a high friction coefficient, it is usual to make F of cast iron and D of leather. A metal to metal contact would slip too much with equal spring pressure, especially if greasy. The pliability of the leather helps in making the engagement soft and steady, and for the best results the leather must be kept soft by occasional treatments of neatsfoot or castor oil. A dry, hard, burned leather makes a fierce, quick grabbing clutch that not only is uncomfortable to the occupants of the car but that also unnecessarily strains the driving mechanism.

To prevent grabbing it is now the practice to place small springs or rubber under loosened parts of the leather facing so that the leather over the springs is raised above the general

surface of the cone. As the high spots first come into engagement, and then are gradually forced down until the whole surface is engaged, the car picks up speed very softly and easily. Small corks inserted in the cone serve the same purpose, the corks being allowed to project above the cone when disengaged.

The cone, and all parts connected with the driving mechanism to the right of the fly-wheel, must be light and have as little momentum as possible so that the cone will not spin long after being released from the fly-wheel member. If the cone spins fast or long after the release it will be difficult to shift the transmission gears and to get the teeth to mesh. Spinning accounts to a great degree for the noise made in changing gears. To reduce the momentum, the cone base is usually made of aluminum or light sheet steel, and in many instances is provided with a braking device that checks the speed of the cone. The brake comes into action only when the cone is released.

As the spring shown must necessarily be very stiff to get the proper pressure on the cone, it exerts considerable end thrust on the bearings, and therefore, causes wear. This has been disposed of variously in the practical clutches by ball bearing thrusts or by rearrangement of the parts so that little trouble is experienced from this source in modern cars. It should be understood that the clutch in Fig. 1 is merely diagrammatic, and is only intended to show the elementary principles of the cone. Practical examples will follow.

Fig. 2 is a cone clutch in which the taper of the cone is reversed, the cone no longer engaging with the fly-wheel but with the female member R, which is bolted to the wheel F. The cone A, which is inside the assembly, has its leather facing D brought into contact with R by the internal spring I. This spring, which acts against the wheel flange at K, and the cone ball bearing thrust S, forces the cone to the right. The ball thrust bearing S reduces the twisting on the spring when the engine is running with the clutch disengaged. It will be noted that with this arrangement there is no end

thrust brought on rotating bearings when the clutch is engaged, and that the friction surfaces are protected against the entrance of dirt.

An external extension, B, of the hub at the right carries the shift collar H, which is actuated by the pedal fork M in the usual way. The pedal lever O is pivoted on the spindle J which is below the shaft N. This position of the spindle reverses the direction of cone movement from that shown in Fig. 1. C is the crank-shaft, P is the pedal, and N is the shaft leading to the transmission, and hence to propeller shaft. Pedal movement is in the direction L.

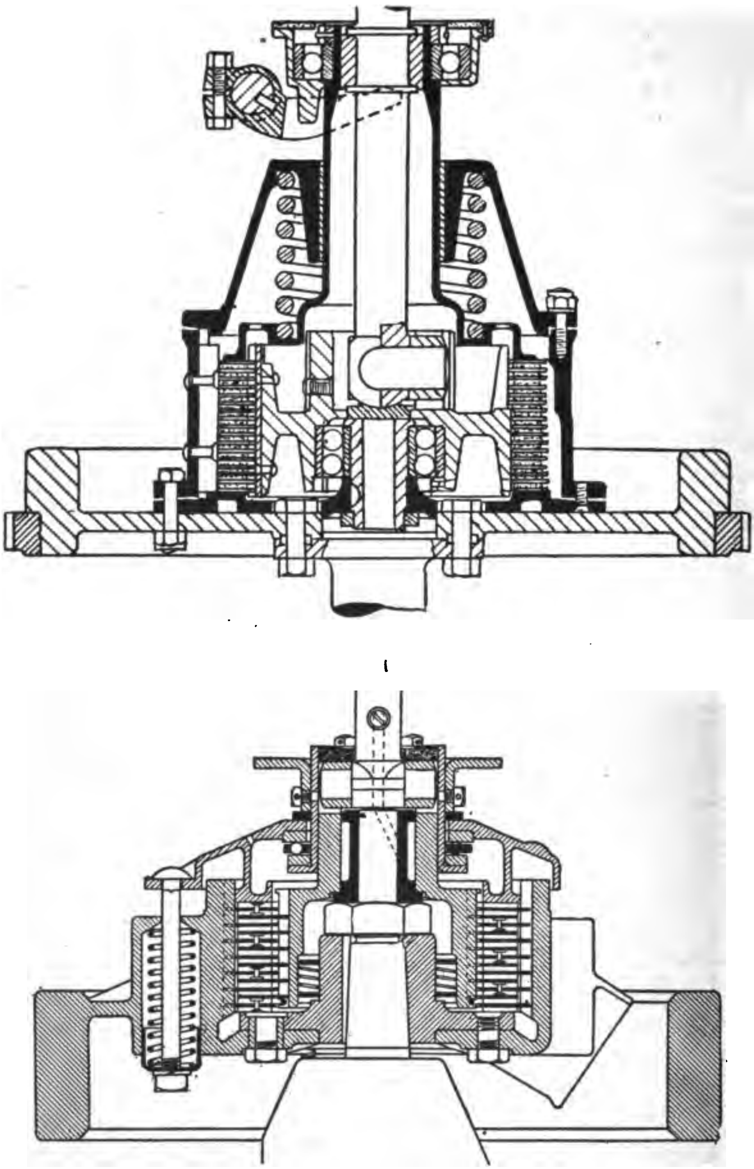
A cone clutch in which bearing end thrust is eliminated is shown by Fig. 3, this being a late model built by the Warner Gear Company. Fig. 4 is another example of this type.

Two methods of procuring a gradual engagement of the clutch leather by means of small special springs or corks are shown respectively by Figs. 5 and 6.

Care of Lubricated Disc Clutches.

Probably the greatest source of trouble with a lubricated type disc clutch is in the selection and maintenance of the oil. Heavy oils are sure to cause trouble by causing the clutch to slip excessively when first thrown in, and by causing the discs to drag when the clutch is supposed to be out. A heavy bodied oil through its viscosity prevents the plates from coming into contact immediately as it will require a certain length of time for the spring to squeeze out the oil. When the plates are disengaged, the high viscosity will create a heavy frictional drag between the two sets of plates causing the gears to spin when shifting and making the shift extremely difficult. Both effects are intensified by cold weather, since a low temperature increases the density of the oil. It needs intelligence and care to insure that the oil is in the proper condition.

Owing to the light pedal pressure required to operate this type of clutch many owners suspect the clutch to be slipping when it is not, and under this impression they tighten up the springs until the pressure is destructively heavy. With an



TYPICAL DRY DISC CLUTCHES.

excessive spring pressure worn plates are the inevitable result. When once worn, the space between the plates increases rapidly and the clutch begins to slip. If not regularly cleaned out, the oil bath becomes a carrier for the particles torn off the plates so that the wear is again increased over normal. Make a practice of removing the old oil at regular intervals through the drain, washing out thoroughly with kerosene, and filling with new clean oil. If badly worn, more plates may be added, or if cork inserts are used they may have to be replaced by new.

When no change of lubricant or outside adjustment will stop the slipping of the clutch, or when it is definitely known through some other source that the parts are worn, it will be necessary to take down the clutch for examination and repair. In dissembling particular attention should be paid to the powerful spring so that it will not unexpectedly jump out of place and injure the parts of the clutch or the operator.

Each plate should be examined separately for rough working surfaces and buckled faces. A slight roughness on one plate may soon show up and destroy the plate with which it engages. Should the roughness be very marked, the plate must either be reground or replaced with new, it often being necessary to replace six or more plates in a single clutch. Buckled plates are generally caused by the heat due to insufficient lubrication, and are causes of erratic clutch action. The buckles can often be removed and the plates straightened by the careful use of a hammer and a block of wood with the plate laid on a perfectly level surface such as a machinist's surface plate.

Should the plates be worn very thin it is usually safer to replace them with new than by adding additional plates to the series. Plates are comparatively cheap and it is usually more economical to replace suspicious parts than to run the chances of being compelled to dissemble the parts a second time.

In installing the new plates see that they fit accurately in the grooves of the casing as well as in the grooves of the shaft drum and that they will move freely back and forth laterally. If tight they should be eased off by a file, taking care that the

filed surfaces are at right angles to the face of the plates and that no burrs or fins are left. Also see that the new plates do not occupy more space than the old plates when they were originally fitted. This can be tested for by fitting up the clutch temporarily, without installing the spring and noting whether the lateral movement on the clutch shaft drum allowed by the clutch pedal is sufficient to allow the faces of the discs to clear and slip when the clutch is fully depressed. With the spring in position it is difficult to make this test.

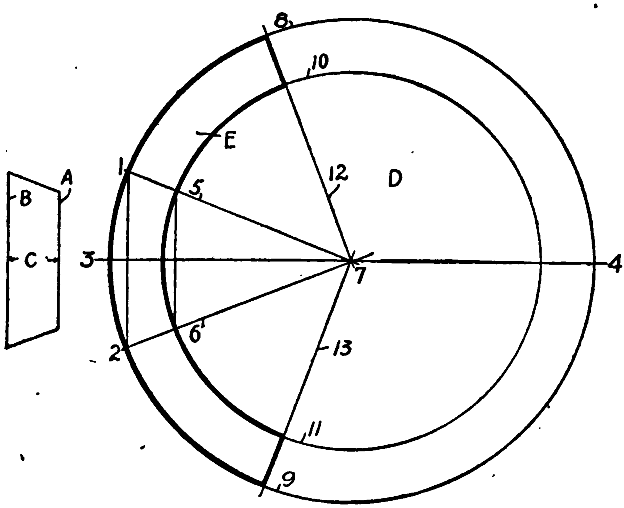
Now examine the inner ball bearings for wear, and if slack exists they should be replaced by new. While misalignment is not of as much importance in disc clutches as in other types it does not improve their working, and in many cases the misalignment, due to worn bearings, has been instrumental in causing fierce engagement and erratic slipping. Again, worn bearings have a tendency to throw stresses into the transmission, causing the gears to run out of mesh and run noisily.

The plate separators separate the plates when the pedal is depressed so that the driving and driven plates slip in relation to one another. See that none of the separators are missing, for a missing spring or stud will cause the plates to drag the change gears with the clutch released, and will cause trouble in meshing the gears. Often these separator springs and studs will drop into inaccessible parts of the casing or will be thrown out with the old lubricant. Search carefully through the old oil for any such small parts before throwing it away.

In replacing the parts the spring will probably be more difficult to place in the assembly than any of the other parts owing to its stiffness and location. A long tube can be slipped over the projecting end of the shaft with a drilled plate at the end of the tube. A long bolt (say one inch in diameter) is inserted into a free hole in the plate, with the head resting against a chassis cross-member. A nut on the bolt presses against the out face of the plate so that the spring can be compressed by unscrewing the nut against the plate. When compressed the clutch cover can be bolted to the housing-flange.

A New Leather for the Clutch.

Owing to the shape of the surface of a cone clutch it is not an easy task to cut a new leather to fit the cone properly. In the first instance take off the old worn leather surface and rivets and be sure to clean out the rivet holes thoroughly. Now that this is accomplished, measure the cone, first taking the diameters of the small end, A, and large end, B, then find the width, C. D represents the projection of the cone in a flat plane. Draw the line 1 and 2, then draw the center line 3 and 4,



CUTTING NEW CLUTCH LEATHER.

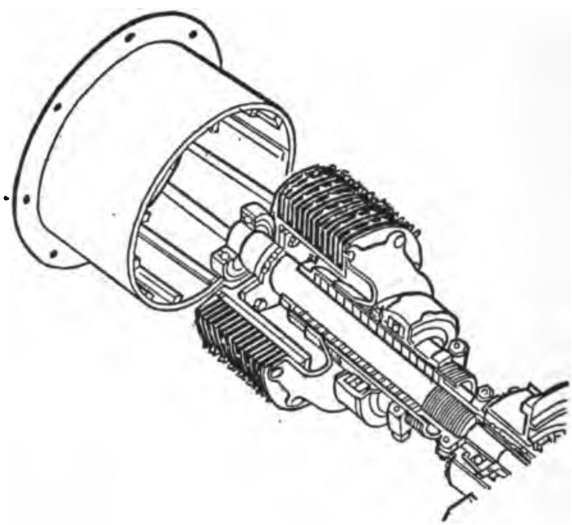
at right angles to 1 and 2. Now prolong the two tapered lines, 1 to 5, 2 and 6, until they meet the center line as at 7. The point 7 represents the apex of the cone, if it were completed, and gives the correct projection of the development of that portion of the conical surface. With 7 and 1, 7 and 5 as radius, draw the two circles 8, 9, 10, 11. Also draw radial lines 12 and 13 to pass through 7. The figure in solid lines, E, can then be cut out of the paper used for the pattern and placed on the leather. Now use the shears and cut close to the edge of the pattern, E, and the proper cover has been made.

Before putting it on the cone soak the leather good in oil. In putting it on the cone, rivet the one end first, next the leather is drawn down past the next rivet holes, which are then driven into place. This is continued until the other end of the leather is reached. Before using the clutch let the leather dry gradually and this will give a tight fit.

Clutches.

The gradual engagement of the Flanders 20 car is secured by a piece of rubber tubing run around the clutch cone and under the leather. This rubber tube takes the place of the corks and springs used in the usual type of cone clutch. The ends of the tube are held by being passed through the holes where they can be seen between the arms of the clutch spider.

When the rubber has lost is elasticity, the clutch may grab suddenly, since the hardened rubber acts like the leather. To fix it, the clutch facing must be removed and a new tube inserted. The facing can be used again, but as it is likely to be well worn it will save a second overhauling if it is replaced by new.



SHOWING DISC CLUTCH DISSEMBLED.

CHAPTER VI

TRANSMISSIONS OR "CHANGE GEARS"

In general, "change gears" or transmissions can be divided into two principal classes: (1) The planetary type in which the gears are always in mesh. (2) The sliding gear type in which the speed changes are effected by meshing different combinations of gears for each speed.

Both types are widely used, the planetary gear in the Ford cars and some makes of light trucks, while the sliding gear type is used in the larger cars and trucks. The selective type of sliding gear transmission is used almost exclusively at the present time.

The following shows a modern selective type change gear, with appended diagrams showing the position of the gears at different speeds. This particular construction gives three forward speeds and one reverse, the third speed or "high" gear being a direct drive at engine speed to the rear axle through the propeller shaft.

The actual construction shown by the longitudinal section is part of a unit power plant installation in which the gear box X is made part of the engine crank case X2. Access to the gears for adjustment and oiling is had through the door Z. The gears in this section are shown in the "neutral" position, that is, out of mesh, so that the engine shaft can turn without driving the propeller shaft.

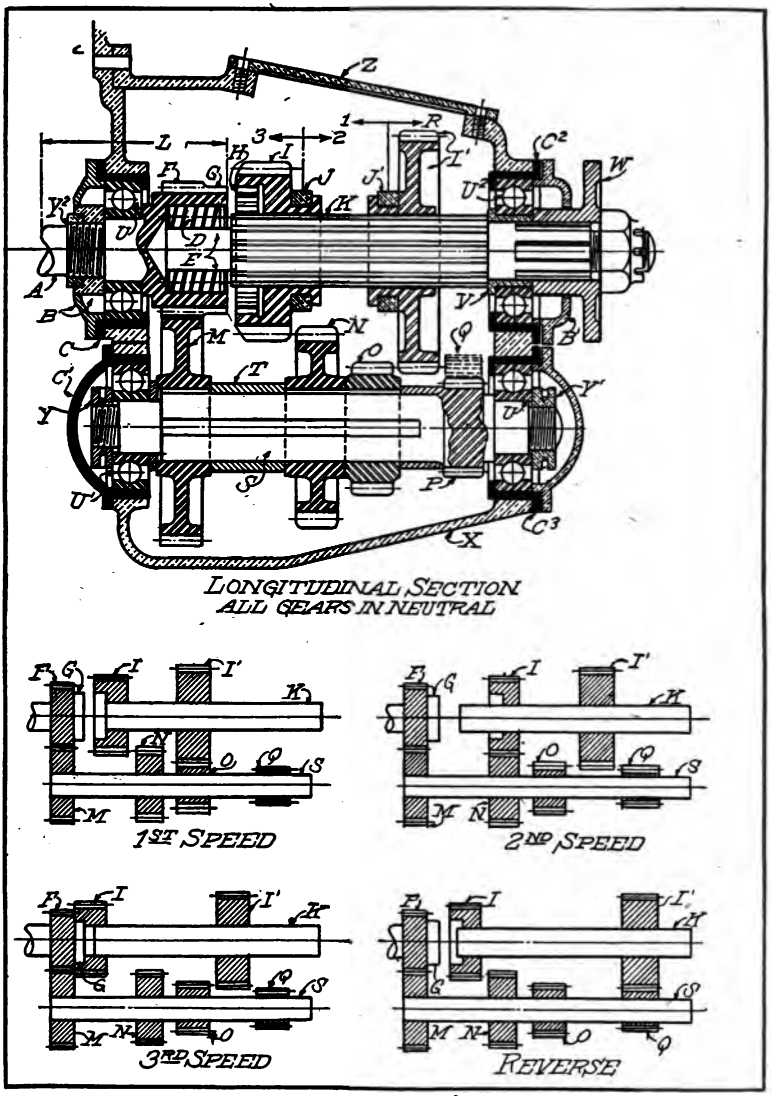
A stub shaft A is connected with the clutch, the latter serving to connect and disconnect the driving member of the gear box from the motor when the gears are being changed. This

shaft, which is carried by the ball bearing U, extends only by the distance L, and is entirely disconnected from the main shaft K except when the car is driven on the third, or direct driven speed. At the right end, the shaft is enlarged and the gear teeth FF and G are cut on the outer circumference. The hollow interior carries the roller bearings D which in turn support the end E of the main shaft K, so that the left end of K is free to turn within the clutch shaft A. This is known as the "Spigot" bearing, or "Spigot" shaft. Since the two shafts A and K turn at different velocities at every speed except third, it is necessary that this bearing be durable and accurate to prevent noise and vibration that would be caused by slack or lost motion in the bearing. The other end of the shaft K is carried by the ball bearing U2.

Both gears, I and I^1, are prevented from rotating on the shaft by the long key-ways shown, or by squaring the shaft so that I and I^1 can be moved back and forth in the direction of the shaft length. The gears are moved by the gear shift lever acting through the collars J and J^1, each gear being moved independently so that I can be brought in mesh with the teeth N or with the teeth G. Gear I^1 can be meshed either with the gear O or the reverse pinion Q. In other words, the gear I gives second and third speeds while I^1 gives first and reverse.

At the top of each gear will be seen two arrows pointing to the right and left, the figures 3, 2, 1, and R indicating the direction in which third, second, first and reverse occur when the gears are moved in the direction indicated by the arrows. Moving I^1 to the left gives first speed while moving it to the right will give reverse. The operating lever system prevents two speeds from being engaged at any one time.

The countershaft S is at all times driven from the spiggot shaft A through the gear M and the teeth F, this being known as the "constant mesh" gear. The gears M, N and O are keyed rigidly on the shaft so that they turn as one unit. The sleeve tubes T are used to space the gears on the shaft. The countershaft is carried by the bearings U and U^1, which



THREE SPEED SLIDING GEAR TRANSMISSION.
The Four Lower Figures Show the Positions of Gears for Three Foreward Speeds and the Reverse.

in turn are supported and protected from dirt by the cages C^1 and C^3.

At the right will be seen the reverse pinion P which is in constant mesh with a second reverse pinion Q. If it were not for the second pinion, and if the gear I^1 came into direct mesh with P, rotation would be the same as when in mesh with gear O, since both turn in the same direction. As Q meshes with P, it turns in the reverse direction, so that I^1 will be turned in the opposite direction when in mesh with Q the idler.

The shift gear I has the teeth I cut on the outside and the clutch teeth H cut on the interior. When the gear I is moved to the extreme left, the interior teeth H engage with the external teeth G cut on the end of shaft A so that the clutch shaft A and the main shaft K revolve as one unit and at the same speed, the motion being transmitted through K and to the flange W. The universal joints are fastened to W so that the motion from the transmission is given to propeller shaft and hence to the rear axles. Any speed whether direct, forward geared, or reverse passes through K and W into the propeller shaft and rear axle. B and B^1 are dust protection stuffing boxes.

Consulting the four lower views we will see the gear positions giving first, second, third and reverse, the letters designating the gears and shafts being the same as in the longitudinal section. Starting with "First Speed" it will be seen that gears I^1 and O are in mesh with gear I out of mesh or in "neutral." Motion from A is transmitted through the constant mesh gears F and M to the countershaft S, there being no direct connection between G and I at this time. With M revolving the shaft S, the gear O meshing with I^1 turns the shaft K at a lower speed. The right end of K being connected to the propeller shaft. The low speed is due to the small diameter of O compared with I^1.

Throwing into second gear, the gear I^1 is taken out of mesh with O, and the gear I is meshed with N, the action being

similar to speed one, except that increased speed is obtained by making the diameter of N greater than O. In the third, or direct driven speed, I^1 is still out of mesh, and the gear I is moved to the extreme left so that the interior of I engages with the clutch teeth on G. This connects the shaft A directly with K so that K and the propeller shaft revolve at full engine speed. This is the normal driving condition.

In the fourth figure is shown the reverse, the gear I being withdrawn and in neutral with the gear I^1 in mesh with the second reverse pinion Q. The direction of motion by gears is now F-M-P-Q-I^1, in order. It will be noted that the gear reduction is greater than in any of the other speeds since P is by far the smallest gear. In following the cuts, reference should also be made to the longitudinal section at the top of the page.

It should be noted at this point that the car must be fully stopped before engaging the reverse gear, as, owing to the opposite directions of rotation of the propeller shaft and reverse gears, when coasting there will be danger of stripping the teeth. Severe stresses will also be developed in the motor and other driving mechanism.

The Electric Gear Shift.

Changing gears with the hand lever has always been an awkward proposition, especially for women who drive their own cars. Shifting the gears has necessitated the removal of one hand from the steering wheel, usually at the time when the car must be maneuvered most carefully as in the crowded city streets. The inconvenient position of the handle together with its long travel has made gear shifting highly inconvenient for short-armed people. In the dark, with the gate at a distance from the operator, there is always a chance of getting into reverse while the car is rolling forward.

With the electric gear shift, the gear changes are controlled by push-buttons placed directly on the steering wheel, so that all positions are directly under the eye of the operator.

Changes can be made without removing the hand a great distance from the wheel. It is impossible to make mistakes owing to the interlocking connections between the clutch and the different speeds. The reach is so small and the operation so simple that it can be performed by a small child.

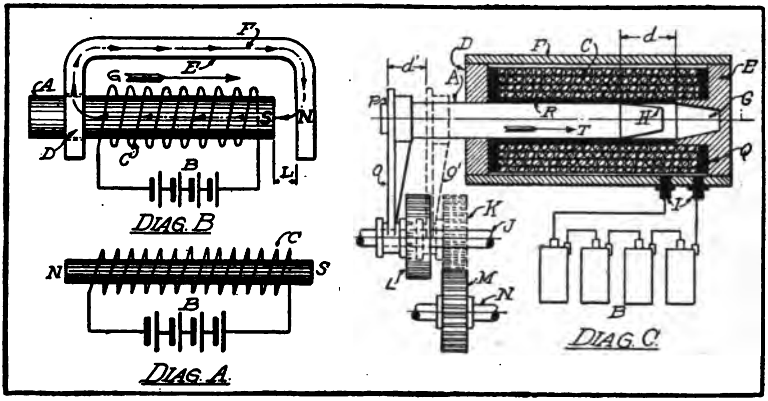
In Fig. A, an iron bar NS is wound with a coil of copper wire C, the ends of the battery B being connected with the coil so that the current flows around the bar in a spiral path. The flow of the current magnetizes the bar causing a north pole at N and a south pole at S. This bar will attract an iron mass and will be drawn towards it. When the current is broken, the magnetism will disappear. In Diagram B, the iron core A is surrounded with the copper winding C, current from the battery B passing through the coil as before. The bar is again magnetized.

An iron yoke E is drilled at D so that the bar A fits closely but freely in the hole. The magnetic field now passes through the yoke and iron core A in the direction indicated by the arrows F, and across the gap L from N to S between the yoke and the end of the core. Since the unlike poles N and S have an attraction for each other, and as the core fits freely in the hole D, the core A will move in the direction of the arrow G until N and S come into contact. This movement can be repeated only by breaking the circuit and pulling the core back into its original position with the gap L between the poles N and S. This is, of course, a single-acting device. A magnet in which the core moves inside of the winding is known as a "Solenoid."

Diagram C shows a solenoid of slightly different construction, the yoke E of Fig. B being substituted by the iron tube F, this also acting to return the magnetic field to the air gap G. The core A is tapered at H to increase its pull through a long travel, the final position of H being at G. The latter pole corresponds to N in the diagram B. The distance of travel is "d." The copper wire coil C is wound on an insulating spool R-Q, there being a small clearance between the tube

R and the core A. The current from the battery B enters the coil through the insulation posts I.

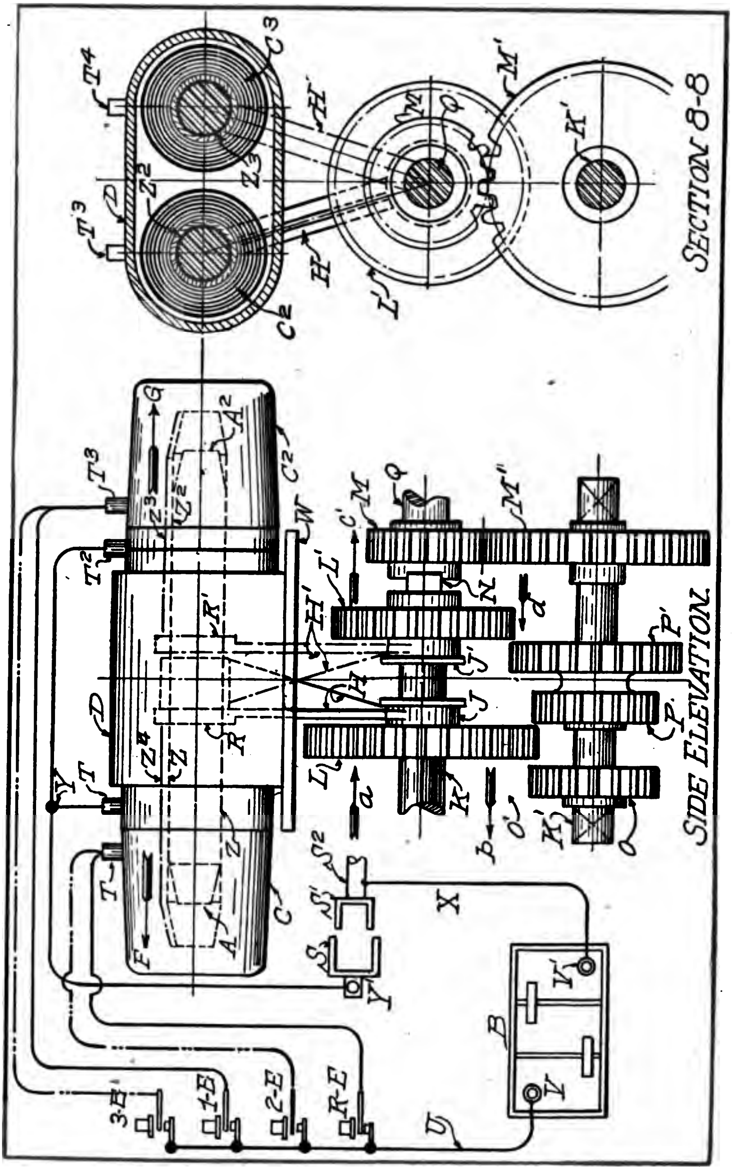
A gear L is keyed on the shaft J so that it is free to move back and forth along the shaft but cannot turn on the shaft. An arm O is fastened on the core A at P and connects with an annular groove at the left of the gear. When the core moves to the right in the direction of arrow T, the arm O will move the gear L to the position K indicated by the dotted lines. The distances d and L-K both represent the travel of the core and gear. With the gear at L, and solenoid dead, the gear L



ELEMENTARY MAGNETIC GEAR SHIFT MECHANISMS.

will be brought into mesh with the gear M when current from the battery B is allowed to flow through the solenoid. To take the gear out of mesh, with this type of solenoid, the circuit must be broken and the core returned either by hand or by a spring. This method of return or dis-meshing would of course be impractical so that it is usual to employ a second solenoid at the end P of the core.

The next cut shows the method used for meshing the change gears on motor cars, there being two solenoids such as C and C^2 used at the opposite ends of both iron cores. The transmission shown, which, is of the four speed type, has four



"VULCAN" ELECTRIC GEAR SHIFT.

solenoids and two cores arranged so that the two gears L and L^1 can both be pulled in two directions. This transmission, as far as the gears are concerned, is very similar to the hand-operated gear already described. As shown by the side elevation, the solenoid pairs are arranged so that the pair C-C^2 is directly in front of a second pair C^3-C^4. The core of the solenoids C-C^2 is indicated by Z-Z^2, while the core of C^3-C^4 is shown by Z^3-Z^4, the rear core being raised slightly so that it can be seen. Section 8-8 shows an end view in which the cores Z^2 and Z^3 can be readily seen. Each end of each core is given a separate number so that the ends can be identified. Current for the operation of the cells is furnished by the storage battery B.

When the first speed button I-E is depressed, current flows from the battery terminal V, through wire U, through I-E and terminal T^3 into the solenoid C^2. The current returns from the coil terminal T^2 to the terminal Y^1 of the master switch on its way to the battery. The switch jaws S-S^1 are normally open, but are brought into contact by the clutch pedal or when the clutch is released. When the clutch is released the current flows momentarily through the coil C^2, which draws the core end Z^2, sharply to the right, and meshes the gear L with the counter shaft gear P. The gear is now in first speed. Another mechanism (not shown) now breaks the circuit.

It will be seen that the gear is not thrown on depressing the push button but only when the clutch is released, and when the switch points S-S^1 are contacted. Thus a certain gear shift can be determined on long in advance of its actual occurrence, so that when the shift is needed, it will not be necessary to press the button but only to depress the clutch pedal. In this way a car can be manipulated in a crowd without using the hands for anything else but steering. It is impossible to throw two gears at once owing to the interlock between the buttons.

The movement of the core Z-Z^2 is transmitted to the gear L through the arm H and the annular groove J. The arm

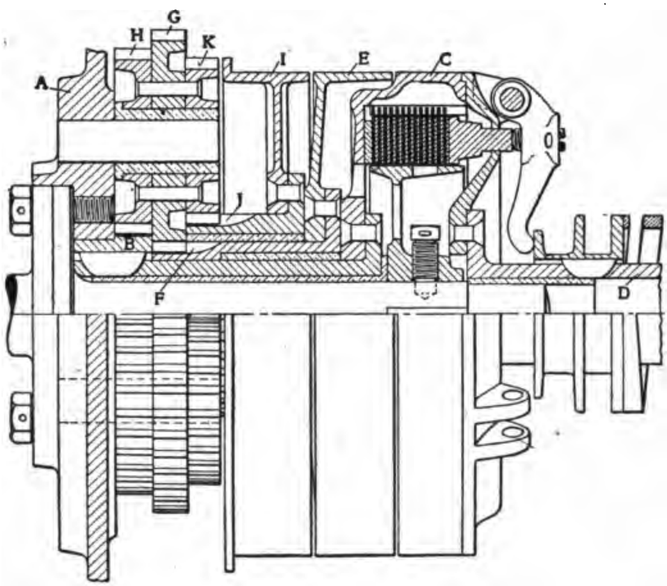
is attached to the core at R. Movement of L in the direction of arrow "a" gives the low speed just attained, while movement in the direction "b" gives the reverse,—that is, when L is meshed with gears O-O^1. The reverse is made by pressing button R-E which energizes solenoid C, and throws plunger Z in the direction of arrow "b." The travel of the current from the battery, through button R-E, to the solenoid, and return to battery is the same as in the first speed.

By means of the two rear solenoids C^3-C^4, the core Z^3-Z^4 acts on the gear L^1 through the arm H^1, shown by dot and dash lines. The arm is connected with L^1 by a collar J^1 in a groove at the left of the gear. Movement in direction of arrow C^1 meshes the clutch teeth of L^1 into the teeth N of the engine shaft Q, giving direct or "high." Movement in direction "d" gives second speed by meshing L^1 with the gear P^1, the latter being mounted on the counter shaft K^1. The propeller shaft is attached to the main shaft K. Energizing solenoid C^3 moves L^1 into direct drive through clutch teeth N. Energizing C^4 gives second speed by moving L^1 in the direction of arrow d. Button 2-E gives second speed and button 3-E gives high, these being connected to solenoids C^4 and C^3 respectively.

The gears are neutralized mechanically by a rather complex system of cams and shafts, not shown in our diagram. Two shafts connected with one another by toothed cams and operated from the clutch through a lever mounted on the end of one of the shafts operates the master switch in such a way that the circuit is broken through the solenoids as soon as the shift has been made. This is to economize the battery current. When the clutch pedal is depressed, the circuit is completed through the master switch, and when the solenoid has made the full stroke, it turns the shafts and trips the spring controlled switch through a trigger arrangement. The inactive gears are brought into neutral by the rotation of the shafts acting through a lever engaging with a trip.

Ford Planetary Gear.

In this type of planetary, the engine drives through a propeller shaft to the rear axle bevel gear, all gears being locked in a mass and inoperative when on high gear, there only being one forward and one reverse geared speed. First speed and reverse are obtained by tightening band brakes on the gear drums. The fly-wheel web A carries the spindles of the triple



FORD PLANETARY GEAR TRANSMISSION WITH TWO FOREWARD SPEEDS AND REVERSE.

gears H-G-K, all being spur gears and bound in a unit mass by rivets as shown. The mass revolves freely on the spindles. The main drive pinion B is keyed to the hub of the clutch drum C which in turn is keyed to the propeller shaft at the right. The multi-disc clutch C is constructed so that throwing the shift collar D will fasten the stub end of the engine shaft (set screwed) to the propeller shaft through the right hand flange

of C, giving direct drive to shaft. A band brake over the outer face of C acts as a transmission brake.

To obtain the first speed, or low gear, the drum E is held stationary by a band brake, thus holding pinion F stationary, cut on the end of the hub of drum E. As gear G meshes with F it rolls around it, causing the triple gear H-G-K to revolve on its spindle. Gear H, meshing with pinion B, causes B to revolve and with it the propeller shaft to which it is keyed. As F is smaller than G, and H is nearly equal to B, the propeller shaft revolves at a lower speed than the engine fly-wheel A, and in the same direction. The small areas cross-hatched by dot and dash lines are the bearing bushings between the drums.

By holding drum I stationary by band brake, the pinion J cut in its hub is also held stationary with the gear K rolling on it. As K is attached to H, and H meshes with B, the motion of the train is again communicated with the propeller shaft, but in a direction opposite to that of the fly-wheel A.

At first it will be difficult to see why holding the pinions F and J alternately will give opposite directions of rotation to B since it is evident that the gears G and K revolve about the engine shaft and their own spindle in the same direction in both cases. Reversal is not due to the reversal of the actual direction of B and H-G-K but is due to a change in the relative velocities between the periphery of H and the velocity of the spindles about the engine shaft.

It will be noted that J is larger than F, and that K is smaller than G, thus giving a higher rotational velocity to the triple gears H-G-K than would be the case with F held stationary. The ratios of the main gears H and B are, of course, the same in both cases with the spindles still traveling at engine speed.

With the higher rotational velocity of H-G-K obtained by holding J, the peripheral velocity of H at the point where it meshes with B is now greater than the velocity of the spindles so that the bottom of gear H forces B back faster than the fly-wheel carries the mass forward.

Consider the top of fly-wheel A to be moving toward the observer carrying with it the spindles and the triples H-G-K. If H-G-K were fastened on the spindles so they could not turn, they would carry B with them at engine speed. Now consider H-G-K to be given a velocity about the spindle in the same directional rotation as the fly-wheel (top of G moving toward observer) so that the bottom of H would move back and away. This would carry B with it, and as the velocity is greater than that of the fly-wheel, the gear B and the propeller shaft would be carried in the opposite direction to the fly-wheel. This is exactly what happened when J drives the triple H-G-K at a velocity greater than fly-wheel speed.

Gear Shifting.

The operation of the clutch and gear-shift may generally best be taken up as one subject, for in cars employing sliding-gear transmissions—and they are the only ones which will be considered in the rest of this article—the proper operation of one depends largely on the proper operation of the other. The clutch, as the reader probably knows, is for the purpose of permitting the motor to be readily and gradually connected or disconnected from the transmission; it should never, except in extreme cases, be used for any length of time as a means of increasing the power by allowing slipping, as little or no "advantage" will be gained by it, and the clutch is apt to be badly damaged. When letting in the clutch on starting care must be taken not to let it grip suddenly. Many clutches will take hold smoothly except at the last instant, and these require special care. When shifting gears the clutch can usually be allowed to engage quickly without jar if the motor has been properly throttled, and this brings up the question of motor control when operating the clutch.

Starting Off.

The very common practice of speeding up the motor when starting is not to be recommended, except in starting on a hill

or when quick starting is very important. A far better way is to accelerate the motor to just a trifle faster than when running idle, and then to gradually open the throttle to prevent slowing the motor as the clutch takes hold. After the clutch has finally taken hold the motor may be speeded up as much as is desired. When shifting gears, disengage the clutch quickly and shift the gears with a quick push or pull —do not "feel" the gears too much—and in the meantime close the throttle almost tight and allow the clutch to come back quickly as soon as the gears have been shifted. To many this may seem a poor method, but the writer has found it excellent. The throttle should be closed just enough so that when going from a lower to a higher speed—from low to second, for example—the motor will have slowed down almost to the speed of the clutch by the time the gears have been shifted, and so that when going from a higher to a lower speed the motor will only have accelerated to slightly more than the clutch speed. In either case as soon as the clutch has taken hold the throttle may be opened as much as is desired. On some cars it will be found difficult or impossible to use exactly this method, and on such cars it is usually best to set the throttle only slightly opened just before making the changes. In general it is best to make gear changes while the motor is running moderately slow, but no cars with small motors or any car when in mud or sand, or anything requiring much power, it is better to keep the motor speed quite high. Certain kinds of motors can be run best at much lower speeds than others; a six-cylinder motor can usually be best run at a lower speed than a four-cylinder motor.

CHAPTER VII

CARBURETERS AND FUEL SUPPLY

Carbureter—An apparatus used to transform the liquid fuel, generally gasolene, into a gas, and at the same time mix it with such a proportion of air as will make it combustible, so that it can be used in a gasolene engine in the same way as ordinary coal gas and air are used in a gas engine.

We may use two different methods to obtain a gas from the liquid fuel. We may draw air through or over the surface of the gasolene and thus vaporize it, or we may spray the gasolene into the air. In either case we have made the gasolene combine with the air so as to form an explosive gas.

The Surface Carbureter.

When we draw air through or over the surface of the gasolene we have what are known as surface carbureters, and these can be divided into three classes:—

1. The type of carbureter in which air is drawn over the surface of a body of liquid fuel and, evaporating, carries off with it a certain proportion of that liquid.

2. The type in which the capillary action of a wick is utilized, and the air is drawn through that portion of the wick above the level of the liquid and carries off with it the evaporated gas.

3. The type in which air is drawn through the liquid.

All these types are practically obsolete as far as automobile work is concerned. The surface type of carbureter is undoubtedly one of the most economical, but it fails through being incapable of rapid alteration of mixture, and on that account has been practically discarded for motor car work.

The Lanchester (English) surface carbureter consists of

a large circular bundle of wicks threaded out at their lower ends, these ends being immersed in gasolene in a large inclosing tank. Warm air is drawn through the upper portion of the bundle of wicks, and coming in contact with the gasolene drawn up by capillary attraction, becomes charged with gasolene vapor, the actual proportioning of the mixture being determined by means of an air cock admitting more or less air to the passage which conducts the mixture from the wicks to the engine. The Ader type, also still in use in Europe, is much smaller, but has materially the same action as that of the Lanchester.

The bubbling or ebullition type of carbureter is another arrangement which though at one time largely used, has now been entirely abandoned for automobile work. The only case extant of this type is a carbureter for crude petroleum. In this device warm air is bubbled through oil heated to ebullition by the exhaust from the engine, and so becomes charged with petroleum vapor.

The Float-Feed Carbureter.

The spray or "float-feed" type of carbureter is now almost universally used. The term atomizer more nearly describes the action of the spray carbureter than any other term. When we force gasolene through a small orifice so that it comes out in the form of a spray we practically break it up into tiny atoms, which are mixed with the air current which causes the spray. These atoms of liquid fuel rapidly become vaporized, and the result is a gas mixture which is highly explosive. The different spray carbureters vary from each other mainly in different means adopted for proportioning the gas and air mixture for different conditions and different speeds of the engine.

With this construction gasolene is kept at a constant level in a jet nozzle by means of a float-feed device. The suction of the engine causes air to flow past the jet, and the vacuum set up produces a flow of gasolene from the jet, this flow being maintained during the suction stroke as a very fine

spray. In this finely divided or atomized condition the gasolene is readily evaporated and taken up with the inrushing air through the inlet pipe to the motor. Generally there are provisions made for admitting more or less air to the mixture after it comes from the jet, or spray chamber, this arrangement being necessary in order that correct proportions of gasolene to air may be approximately maintained.

The multiple jet type of carbureter is a development of the ordinary jet or spray pattern. With it there are a series of jets having various sizes of nozzle. The smallest is used at the lowest speed of the engine, while the increasing diameters are used either separately or in conjunction with the preceding jets as the speed of the engine is increased; it being evident that at a low speed, unless a very fine orifice is provided, the spraying effect will not be obtained, while with increasing speed and suction it becomes necessary to increase the area or orifice in order to get the requisite amount of gasolene through.

Originally all carbureters were made with a mixture supply and a source through which additional pure air might be drawn, and regulation was accomplished by opening or closing this supplementary air supply from the driver's seat, the accomplished results, of course, being in accordance with his skill.

In the early days of the 20th century, Krebs, a French engineer, invented what may be termed the first automatic carbureter in which the mixture was regulated automatically by the speed of the engine; flexibility being thus obtained to an extent hitherto undreamed of. This invention paved the way for, and inspired, a vast number of others of greater or less merit, but it also gave rise to one theory that has since been proved erroneous, namely, that in order to obtain the best results the engine should be fed by a carbureter which automatically keeps the proportion of air to gasolene always the same. It was on this principle that the majority of designers worked, and the result was that for a considerable

time there was a deadlock in carbureter design. Every one had in view an erroneous condition and, where their efforts to satisfy this condition were the most successful, the actual results obtained were the poorest. Experience since derived indicates that in order to obtain maximum flexibility from an engine the mixture must be slightly richer in gas at low speeds, while it may have increased air proportion as the speed develops. It is on this principle that most of the carbureters fitted to modern machines now operate, although such operation is very largely obtained automatically from the engine speed.

In all spray carbureters it is necessary to provide means of

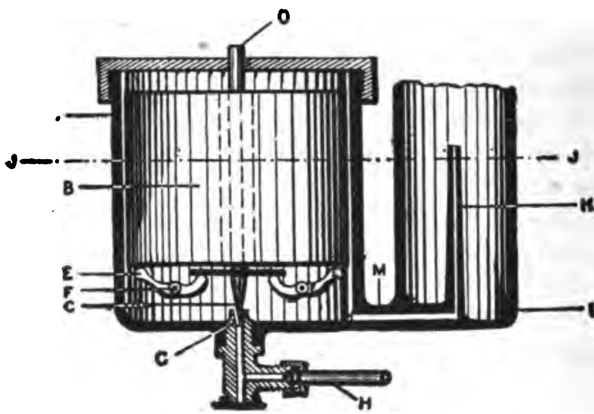


Fig. 1—Carbureter Float Chamber and Jet.

keeping the gasolene at a constant level. If it were fed direct from a tank to the spray nozzle it would have a constantly varying weight of liquid behind it, as the tank was filled up or emptied. This would result in varying sprays, irrespective of the varying suctional effect of the engine at different speeds. It is desirable that the inertia of the fluid from which the engine sucks the spray shall be constant, so that some constant level device becomes necessary.

The float feed meets this requirement, and is practically the same in all types of carbureters.

A diagrammatic view of the float mechanism is given in

Fig. 1. A is the float chamber, supplied with gasolene through the inlet H. C is a needle valve, shutting off or opening the gasolene inlet. There is a collar around the needle valve, the weight of which keeps the latter normally closed. B is a float formed of a hollow chamber of light brass or other metal which floats in the gasolene. M is the outlet from the float chamber conducting the gasolene to the spray jet K in the spraying chamber L. The level of the gasolene normally stands at the height of the line J J, that is to say, just below the top of the spray nozzle K. When gasolene is sucked through the nozzle K by the engine the level of the gasolene in the float chamber is lowered, and the float descends. In doing so it comes in contact with the top ends of the levers E E pivoted at the points F F, and depresses them. The bottom ends of these levers then come in contact with the collar on the needle valve spindle, raising it and admitting more gasolene until the level is regained. It will be seen that the action takes place automatically, and the level of the gasolene in the float chamber and in the spray nozzle is retained at a constant point. This device is common to practically all spray carbureters, and whether the gasolene is supplied by gravity from a tank higher than the carbureter, or forced under air pressure from a tank at a lower level, does not in any way alter the working of the device.

The cross-section of the New Speed carbureter is shown herewith, in which the engine connection is at the top, air entrance at the left, and fuel at the right. The suction of the engine raises the piston and admits more or less air through the air port at the left as indicated by the arrows, and at the same time acts on tapered fuel valve B (Metering Pin), so that the fuel and air are taken in at the correct proportion. The metering pin B is uncovered by the raising of the piston A in proportion to the suction created by the engine piston. By an annular port extending around A, the air enters the mixing chamber at uniform intervals around its circumference. To adjust for low speed, the screw lever C is turned to the left for more and to the right for less fuel. When the motor idles

properly with retarded spark, the carbureter is adjusted for all speeds. There are no springs, dials, jets or other complications found in the conventional carbureter.

When idling the piston A is in the lowest position, which closes all ports and allows fuel to enter through small passage at B, the annularly arranged ports through which the fuel enters the mixing chamber as spray will be seen in the center

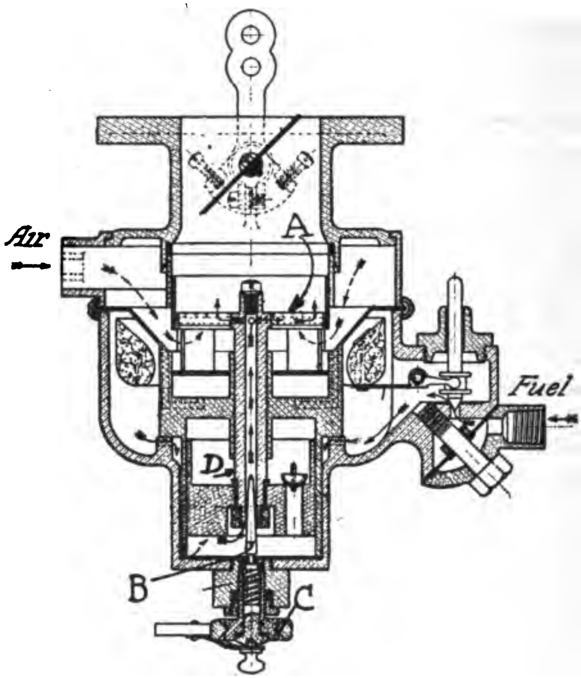


FIG. 2.—NEW SPEED CARBURETER.

and directly above the piston A. The central tube D rests on the metering pin B and being in one part with the piston A, admits fuel to its bore when lifted off the metering pin. From this point the gasolene ascends to the spray openings above the piston. The higher the piston lifts the more fuel will flow, and the more will be the air admitted through the upper ports.

Edward's Carbureter.

This carbureter has a number of novel features, among which is the method adopted in handling the atomized gasolene after it has left the nozzle. It has been found that if the particles of gasolene are broken fine enough to be carried in

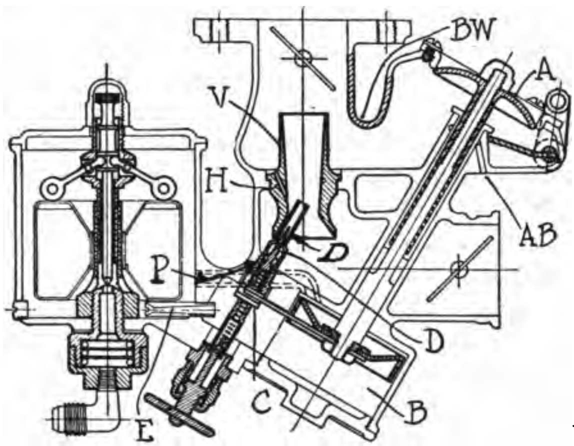


FIG. 3.—EDWARD'S CARBURETER.

suspension by the air, that they will revert into large drops on striking any solid surface. This is prevented in the Edwards' carbureter by the gas, great speed in the Venturi tube V, shown by Fig. 3, and then by surrounding it with an outside wall of air, which holds the original gas in the center and out of contact with the walls of the device. In this way the particles delivered to the cylinders are exceedingly fine and capable of complete gasification on the smallest application of heat. An inside metering needle D, meters the fuel and keeps the gas from touching at any point. This needle is controlled by the air valve A by a bridge bar at the lower end of the air valve spindle. The bridge sets over a collar on the needle at C, thus moving the metering needle directly with any movement in the air valve A.

At the lower end of the air valve spindle is the piston or dash-pot B acting on the gasolene in this chamber. When the throttle is suddenly opened, the suction opens the air valve and through the rod, and piston B, exerts pressure on the gasolene, which was drawn from the float chamber through the passage P (shown dotted). The compression of the gasolene through this movement compensates for the lack of gasolene on quick throttle opening and increases the acceleration of the car by forcing gasolene into the air stream around the needle valve. A horizontal Venturi tube E from the float chamber to the compression chamber allows the gasolene to flow freely in one direction from the float chamber, but slowly in the other so that the compression will not be interfered with by the fuel supply from float chamber. This avoids the use of a check valve.

The single jet enters the Venturi tube V at an angle, the latter serving to increase the speed of the air. The baffle BW restrains the air from the valve A to pass the Venturi in a vertical direction so that the gas will not be blown to one end of the manifold. The heated primary air passes around the Venturi not only to warm the gas but to keep the Venturi hot. After this is warmed no heat is further applied, since a further rise in temperature would lower the volumetric efficiency. A drain hole H returns any condensation in the mixing chamber to the Venturi, thus preventing loading with a quickly opened throttle. A starting lever both regulates the vacuum and seals the air valve to give a rich starting mixture. The weather adjustment is made by a spring which varies the vacuum in the carbureter. A hole AB is to relieve the vacuum on the air valve stem.

Air Valve Types.

The Krebs type can today be considered the simplest form of carbureter which operates satisfactorily and there are several different models now manufactured based on the prin-

ciple of the auxiliary air valve only. In these the problem is worked out in different ways. One manufacturer uses a spring-controlled valve; another hopes to get better results by regulating the movement of the valve by two springs, instead of one; still another maker adds an air dashpot with the hope of getting finer regulation and a better functioning of the auxiliary air valves; another uses a dashpot filled with gasoline; and there are others who use metal balls to serve as the auxiliary valve; while others use what are known as weighted air valves. While they all differ in the details of working out the design they are, nevertheless, based on the basic principle of the auxiliary air valve as originally worked out by Krebs.

Metering Pin Class.

The next type of carbureter may be referred to as the metering pin class. This division incorporates all that is in the air valve or Krebs classification but goes further and inserts a metering pin, which is a pin with a bevel point in the nozzle or jet from which the gasoline issues. This pin is inserted with the object of regulating the flow of gasoline, and is used in addition to the auxiliary air valve so that this type incorporates four basic features: the float control, the auxiliary air valve, the nozzle in the air passage and lastly, the measuring pin in the nozzle.

The Schebler metering pin is not stationary but is designed to be either raised or lowered so as to regulate the size of the opening through which the gasoline issues A conventional form of it is usd on one Schebler model. The metering pin is linked with the throttle so that as the throttle is opened the metering pin is raised out of the nozzle so as to increase the flow of gasoline in a desired ratio with the increased air.

There are other designs which move the metering pin other than by the throttle, in fact, in the latest model T Schebler, the metering pin is controlled by the auxiliary air

valve. When the valve moves downward, opening, it carries with it the metering pin which extends downward into the jet and is desired to increase the jet volume as it is lowered, whereas in the older Schebler type the jet volume is increased by raising the metering pin. In both the auxiliary air valve is used. In one it is controlled by a spring and in model T by a dashpot and spring.

There are other carbureters in which the metering pin is regulated by what is known as a metering air valve, in short, a measuring air valve to control the measuring gasoline pin. An example is the Stewart, in which the metering valve is rather a complex affair. The metering pin stands vertically in the center of the valve and can be located by the collars on the lower end meshing with the small adjusting wheel by which the pin can be raised or lowered as desired. Normally the metering air valve by its inverted cone-shaped top fills the entire air space, the only open space for air to pass being through two small openings. These passages have air capacity for only very low speed and as soon as the motor requirements exceed this volume the suction of the engine begins lifting the entire air valve. The higher this valve is lifted the wider is the space between it and the metering pin and the greater the volume of gasoline permitted to pass the jet. Also the greater the volume of air passing between it and its seat. By the adjustment provided at the base of the metering pin, the pin is set to supply a definite amount of fuel when the air valve rests on its seat. In order to get the best possible action of the air valve the lower end of it is in the form of a piston constituting a dashpot operating in a gasoline well. This dashpot gives a more uniform movement and prevents the valve from fluttering.

Multiple Jet Carbureters.

Multiple jet carbureters are often employed, particularly where a large range of flexibility is aimed at. In most of them there are from two to four jets which are unveiled to the incoming air in turn, and are either used one at a time (the commencement of a second jet causing a cessation of the first), or else in a series. In one of the simplest and most novel the spraying nozzle runs obliquely from the corner of the float chamber into the spraying chamber, and contains inside it a loose toothed rod, with some five or six serrations. In order to reach the spraying chamber the gasolene has to pass over the serrations cut in the rod, and these offer a certain amount of opposition to its passage. When the speed of the engine increases and the suction becomes great, the rush of the gasolene is interfered with to a greater degree than when the speed of the engine is slow and the suction is slight. In other words, when the gasolene dashes up against and into the angle of these serrations, the stream doubles back on itself, so to speak. Approximately correct mixture is therefore maintained at all engine speeds. Different sized toothed rods are supplied with each carbureter, so that the motorist can experiment for himself until he gets the best results.

Functions of the Carbureter.

In answer to the question of the novice, "What does the carbureter do?" it may be said broadly that the carbureter brings together a portion of liquid gasolene with about 8,400 times its volume of air, divides the liquid up into so fine a spray that the mixture of the air and liquid is made very intimate and complete, and provides means for keeping this mixture correctly proportioned under the varying working conditions of the engine.

Essential Parts.

The essential parts of a typical float-feed carbureter may be stated as follows:

1. A small pipe which supplies gasolene to the float chamber.

2. A float which, when raised by its buoyancy, inserts a needle into, and thereby closes the small supply pipe.

3. Another small tube which leads gasolene away from the float chamber to the spray nozzle.

4. The spray nozzle or jet which squirts the gasolene into the middle of the stream of air which is on its way to the engine.

5. The air duct along which the air (which is very often hot air) is made to pass when the engine makes its suction stroke. The parts of this air duct are called by different names, as follows: From the place where hot air enters a gauze filter at the mouth of the duct up to the near neighborhood of the jet, it is perhaps most usually called simply the hot-air pipe and is often made of copper. All round about the jet itself the shape of the duct generally changes. It is called the spray chamber, and is usually made of cast brass. Beyond this, from the spray chamber to the engine, it is called the inlet, induction or mixture pipe, and is sometimes made of copper, though sometimes it is a casting.

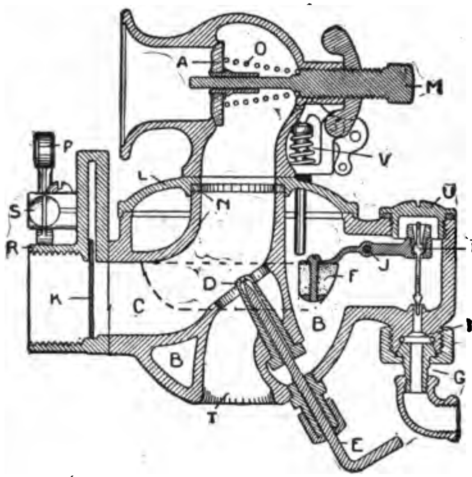
6. In the length of the mixture pipe is often inserted a device called the auxiliary air valve. This is an automatic device introduced to secure the different qualities of mixture gas required under the varying conditions of travel.

7. Further on in the length of the mixture pipe is the throttle valve, which the driver can open or close at will by moving a small handle somewhere on the steering column.

Quality of Mixture.

The automatic extra air valve was introduced to give to the engine at high speeds a diminished quantity of gasolene per stroke. This fact is often stated differently, namely, that it was introduced to give more air at high speeds than at low speeds, but this is the wrong way to put it. More air is available, but it is not and cannot be taken by the engine, for reasons which will appear later. Agreeing for the moment

that from 40 per cent. to 25 per cent. less air per stroke is taken in at high speeds with or without an automatic valve (at, say, 1,500 revolutions), than at low speeds (say, 150 revolutions per minute). This taking of less air per stroke is the chief and first reason why less gasolene per stroke must be



The Schebler Carbureter—Model E—Section.

A Compensating air valve
B Float chamber
C Mixing chamber
D Spraying nozzle
E Needle valve
F Float
G Reversible union
H Float valve
I Float connection
J Float hinge
K Throttle
L Float chamber cover
M Air valve adjusting screw.
N Cork gasket
O Air valve spring
P Throttle lever
R Pipe connection
S Throttle stop
T Fixed air opening
U Float valve cap
V Flushing pin

given if we wish to maintain what may be called the normal proportions of mixture. Notice here that we cannot hope to avoid the taking of less air even by making smoother and larger air passages and valves, since the chief impediment is not the friction of the air against the pipe walls, but the inertia and elasticity of the air which prevent our giving it

the necessary acceleration in the short time of a suction stroke when the engine is going fast.

Reason 2.—Besides this chief reason, there are subsidiary reasons why less than the normal flow of gasolene per stroke is wanted at the highest engine speeds. Thus there is increased compression at high speeds, and this affects the matter of the most desirable mixture very appreciably. The volume sucked in is about one-third less, but the compression is effected ten times faster, and this means a hotter compression, and therefore a higher compression, than if the same amount of gas were compressed in the same engine more slowly. To prove this, consider the two extreme cases of speed, namely, infinitely slow and infinitely fast. The difference of pressure can be calculated, and it is enormous. In an engine of which the ratio of compression was only 3.63 to 1, 42 lbs. compression was calculated in the one case, and 89 lbs. in the other, taking a supposed full charge of air in each case.

If the engine of the example had had the usual "five-to-one" compression ratio, this would mean bad pre-ignition with a normal mixture, and a poorer mixture automatically given would be necessary to save the situation at high speeds, unless we submit to the inefficient process of diminishing the compression by strangling the volume of incoming gas.

There is also another fact which operates in the same direction as the last, namely, the diminution of all small leakages of gas past the piston rings and valves, spark plug, inspection cock, plugs and joints, when the stroke is rapid, all making for an increased compression, and therefore, from a carbureter point of view, all pointing to the desirability of a poorer mixture and therefore an extra air valve.

Reason 3.—The high and hot compression is further enhanced by the incomplete discharge and high temperature of the unexpelled residue of the exhaust from the previous stroke, and the consequent greater initial temperature of the heterogeneous mixture which constitutes the explosive charge.

Reason 4.—Still another reason for requiring at low speeds

more gasolene than the average per stroke, and incidentally therefore for requiring an automatic valve or its equivalent, is based on a totally different consideration. At the limit of slowness with a normal mixture we fail, even with a retarded ignition, to keep the engine rotating, because of the evanescent character of the explosion pressure and the failure to ignite, or at least the incomplete inflammation of the charge, which would be much throttled down for slow turning, and therefore poorly compressed. But we find by experiment that a slightly more durable explosion pressure is secured, and much more certain ignition is obtained, when the mixture is rich in gasolene. We therefore decide to employ a rich mixture when running slowly and to put up with the drawbacks of a rich mixture, which are that we do not get complete combustion of the gasolene. We take the risk of a little smell and waste of fuel for the sake of having a "flexible engine."

There are many other ways of regulating the quality of mixture besides the use of the automatic or auxiliary air valve. It is largely a question for the engineer. The engine and the carbureter must be "tuned up" together to secure the best results.

One important practical condition amongst many has already been mentioned—it is known popularly as the condition which shows up the "flexibility" of the engine.

A "flexible" engine is one which continues doggedly to do a modicum of useful work when rotating quite slowly. The term "flexible" does not exactly fit the case, but it has become established. This property is assured not only by having the rich mixture at low speeds but also by increasing the number of cylinders, using mechanically operated inlet valves, increasing the size of the compression volume in relation to the piston displacement, etc. These engine matters again bear upon carbureter design, because they affect the rate at which the gas is called for and the manner and frequency of that call—proof again that engine and carbureter must be fitted to one another as carefully as a boot to a gouty

foot. It is quite interesting to summarizé the number of evils which, though sometimes due to other causes, may often be due to a badly adjusted carbureter. Sooted spark plugs, boiling of radiator, eroded exhaust valves, loss of power, misfiring, waste of gasolene, failure to pick up until some moments after any new position of the throttle has been adopted, smelly exhaust, "popping" behind the inlet valve, explosion in the exhaust box, pre-ignition with resultant damage to crank-shafts or connecting rods, failure of the engine to stop when the spark has been interrupted, etc., etc.

In view of all this, it is small wonder that manufacturers have been kept busy experimenting with innumerable methods and suggestions for varying the quality of the mixture in some manner remotely according to the conditions of its employment.

A Cause of Heavy Gasolene Consumption.

One source of excessive gasolene consumption is the heating of the carbureter to a much higher degree than is necessary, so that, independently of the suction by the motor a comparatively large quantity of gasolene is drawn through the jet in the form of pure vapor. This added to the subsequet charge of gasolene drawn through the jet by the suction of the engine makes up the large quantity of liquid used. The resultant cylinder charge is, of course, much richer than is necessary or good for the engine, as sooty valves and plugs nearly always result. We use the words "nearly always" advisedly, as some engines have their valves and plugs so placed that they are automatically cleaned by the exhaust gases, one charge sweeping before it the soot deposited by the previous charge. Again, in other engines, the plugs, or, perhaps, the valves alone, are so placed as to prevent the accumulation of carbon deposit. We mention this, as probably some readers will wonder why their valves and not their plugs become dirty or vice versa.

Having given a probable cause of the trouble, we suggest a remedy which, to many readers, will be perfectly obvious,

and that is to cut off the hot air or water, as the case may be, from the heating chamber by means of a simple cock. It is only when running through a keen frosty air, or when the atmosphere is heavily charged with moisture, that the heating chamber is actually required, yet on many engines no provision is made for cutting off the source of heat, hence the increased gasolene consumption.

Letting in More Air.

There is no doubt that many cars waste a lot of gasolene simply because the carbureters do not supply sufficient air. In this matter, car owners might well take an example from motor cyclists. Speaking generally, motor cyclists realize the advisability of using as weak a mixture as possible, and after a motor cyclist has passed his novitiate it is quite the usual thing to find that he has so altered or adjusted his carbureter that he can always command an adequate supply of air, as very few cycles are turned out with provision for a full supply. It is not merely a question of economy of gasolene, though that is quite an item, but in many cases more power can be obtained from the engine, and it keeps much cleaner, while the valves keep cooler and the smell from the exhaust is much less if the weakest possible mixture is used. An extra air inlet is therefore a good thing and there are many ways of increasing the air supply.

Water in Air Pipe.

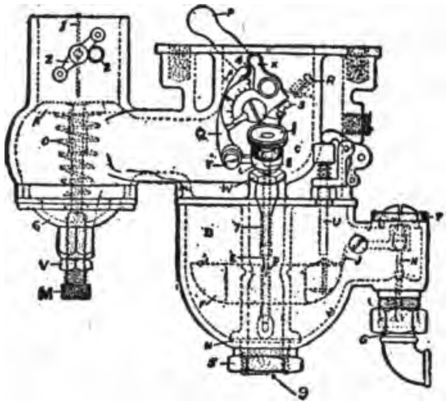
The air supply pipe to carbureters of most cars is arranged so that the pipe can be open to the air, or made to take its air from round the exhaust when the temperature of the outer air is so low that good running cannot be obtained unless the air be heated. On many cars the air pipe is high up and well out of the way, but there are a number which have the pipes so arranged that when the car is washed, some of the water may splash into it at the cold air slot. We have come across instances in which this has occurred, so that the water has been sucked into the carbureter; then if the engine does not run well, it has been assumed that there

was water in the gasolene, though, as a matter of fact, any small quantity which might enter through the induction pipe would really do no harm. At the same time, when one sees water dropping from the carbureter, it is only natural to assume at the first glance that it is caused by water in the gasolene. However, we give the hint for what it is worth; as if the idea is once obtained that there is water in the gasolene, a lot of trouble will be taken for nothing. There is also a certain amount of condensation in the induction pipe, and beads of moisture may be noticed in it from this cause.

Flooding Carbureters.

When persistent flooding of carbureters occurs, it is generally due to one of two things: Failure of the needle valve to seat properly, which can, of course, be overcome by grinding in the valve, or to a punctured float, which allows a small quantity of gasolene to enter, and thus upset the balance and allow the gasolene level to rise higher than it should do, and consequently to flood. This can be easily discovered by shaking the float, when the liquid can be heard inside. To find the hole and get the gasolene out is somewhat difficult, but the following is the simplest way: The float should be put into very hot water and held beneath the surface. The heat causes the gasolene to gasify and be driven out through the small hole, when the issuing bubbles will make it clear where the hole is. The float should be thoroughly cleared of gasolene, and the hole stopped up with solder. In doing this, it is a mistake to put as little solder as possible on to the hole, but the job should be done thoroughly and be cleaned afterwards with fine emery paper. Of course, care must be taken not to allow too much solder to remain on, so as to upset the balance of the float, and not to allow the solder to get into the float. Silver solder is better than soft solder for this purpose. If after the hole has been closed a slight leakage follows which it is impossible to locate, a good method of preventing further trouble is to give the whole float a good coating of nickel by electroplating it. This closes up the small porosities better than any solder will do.

With carbureters of the Longuemare type, with a weighted needle, flooding is sometimes due to a third cause. The weight occasionally bears on the seating, and does not allow



The Schebler Carbureter—Model F—Section.

A Compensating air valve
B Float chamber
C Mixing chamber
D Spraying nozzle
E Needle valve
F Float
G Reversible union
H Float valve
I Needle valve adjusting screw
J Float lever
K Throttle
L Needle valve retainer
M Air valve adjusting screw
N Cork gasket
O Air valve spring
P Throttle lever
Q Needle valve lift lever
R Throttle stop
S Pivot screw
T Float valve cap
U Flushing pin
V Lock nut
W Needle valve hex connection
X Spring cam casting
Y Eccentric high speed adjustment
Z Air valve shutter lever
1 Air valve butter-fly disk
2 Spring
3 Lock screw
4 Cam spring
5 Lock nut for bowl
6 Air valve cap
7 Needle valve retaining spring
8 Needle valve spring
9 Constant air opening

the needle to seat properly. The result is that flooding occurs either continuously or intermittently when the motor is running, as then the vibration shakes the needle from its seat.

Warming the Carbureter.

A kink applied very successfully for starting the engine when the atmosphere is chilly is simply to fill an ordinary india-rubber hot-water bottle and apply it as far round the carbureter as possible, leaving it there for a sufficient period

to enable the carbureter itself to draw some heat and thus assist vaporization. Another method is to wrap around the carbureter some absorbent material, such as large size lamp wick, which can be carried for the purpose, and to pour over this hot water, repeated applications of which will raise the temperature of the carbureter even higher than will be obtained by the usual heating by a branch from the exhaust.

The Freezing of Carbureters.

"During a snap of frost," writes an enthusiastic automobilist, "we had an experience with one of our cars which may prove a warning to others. While the cooling water circulating system was in a sufficiently warm place to prevent its freezing up, yet it did not protect the carbureter from the effects of the frost. This particular carbureter has a hot water jacket around the mixing chamber, which is in close proximity to the float feed chamber. A single cock is provided to prevent the water circulating round the jacket when extra heat is not required, but it was impossible to drain the water from the jacket. The low position of the carbureter, and the lower temperature occasioned by the near presence of gasolene, were too much for the water around the carbureter, and it froze up. A natural consequence was that something had to go, and, fortunately, the weak spot was found at a plate soldered over a clearing hole in the water jacket. This gave way, and when the thaw came we had a fountain display beneath our engine bonnet. As a protection against similar occurrences, we had an extra cock put into the circulation pipes on the other side of the carbureter, and a drain cock put into the lowest point."

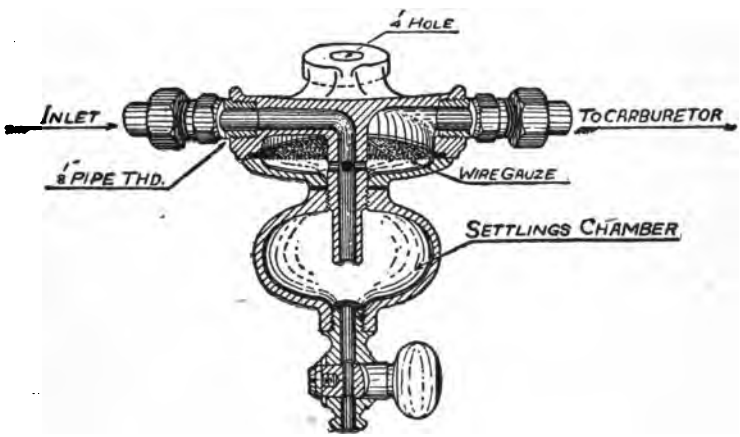
When the Jet is Blocked.

Few owners care to take down a carbureter by the roadside, especially as some carbureters appear to be constructed with the sole object of making it as difficult as possible to get at the jet. When the jet is blocked it is always well to try flooding before taking the trouble to pull the carbureter to pieces. Many automobilists know this little wrinkle, but

plenty do not. It is simply a matter of holding the float down or up, according to which way the gasolene is admitted, so that the full head of gasolene in the tank may come through to the jet. In nine cases out of ten it will free it—possibly only temporarily, but still enough to enable one to get along and to postpone the taking down of the jet till one gets home. When once the engine has been got going again one can keep a careful ear upon its running, and directly it shows signs of flagging, race it a bit, and race it with the extra air inlet (if such is provided) closed. This puts so strong a suction on the jet that it will often remove the obstruction, and that without stopping the car.

Choked Carbureters.

One of the most exasperating of minor troubles which can fall to the lot of the motorist is to have a partially choked



The Schebler Fuel Strainer—Cross Section.

gasolene jet in the carbureter. If the jet were wholly blocked up and the engine could not be run at all, one would naturally go to the carbureter (if not at once, directly after testing the ignition), and the cause of the trouble would be revealed. On the other hand, when there are particles of foreign matter floating about, they will keep more or less clear of the jet,

but they are never far away. You flood the carbureter and start up the engine, which runs merrily for a few revolutions, coughs, chokes, and stops. What has happened? Those free bits of dust which were merely agitated by the action of flooding the carbureter have by the constant suck exerted by the engine been drawn up into the jet and effectually blocked it. The engine being stopped, the bits fall away from the jet again, and so the process of numberless startings up of the engine is performed. Now, if the ignition be found in order, and the gasolene feed to the carbureter be clear, it is nearly always advisable to proceed to the jet and clear it out straight away. While the jet is out, run some gasolene through the jet orifice to wash away any particles which may be left behind. The jet being clear, it may be replaced and flooded, in order to ascertain that all is perfectly in order.

Attention to Automatic Carbureters.

Automatic carbureters, like many other good things, require keeping thoroughly up to the mark, otherwise they are apt to become a source of trouble. A great many of the automatic carbureters now in use have a sliding plunger or piston, the suction of the engine on the plunger causing a greater or less opening of extra air inlets. Now, when taking in air through these extra orifices, of course, whatever dust or other foreign matter is present in the air is taken in past the automatic piston, and, since moisture usually condenses about this part, the dust is there deposited. The effect of this is to cause the piston to stick or work erratically, this having a bad effect on the running of the engine, apart from increased gasolene consumption. Some automatic pistons are made so that they can be readily detached, so that in such a case all that it is necessary to do is to see that the piston is washed out pretty frequently, but in cases where such cannot be done it is a good plan to get a small syringe and wash the piston orifices thoroughly with a spray of gasolene, which does the job quite as well. Of course, in doing this, care must be taken that no naked lights are in the vicinity of the car-

bureter, nor until the gasolene vapor is thoroughly removed must a lighted match be thrown on the floor, otherwise a fire is certain to ensue.

Another frequent cause of trouble with automatic carbureters is that due to the spring losing its tension or in other ways getting out of adjustment. There is usually a small nut or pair of nuts fitted, which can be screwed up or down to alter the tension or pressure on the piston controlling spring, and sometimes such nuts are rather likely to shake loose and alter their position relative to the stem on which they are screwed, thus altering the spring tension. These should be examined from time to time to assure the user that they are in the correct position. When the spring becomes too weak, either a new spring must be fitted, or, as a temporary measure, the old spring can be removed and carefully stretched and then replaced, the adjustment being made by means of the nuts, as before mentioned.

Air Inlet Gauzes.

Assuming the gauze to take up three-quarters of the air inlet—which is usually the case—the area of the gauze should be made about four times as large as the actual air inlet.

This is provided for by supplying a funnel over the mouth of which the gauze is to be fixed. As an alternative, if the funnel cannot be fitted, the gauze should be made into a cone and slipped inside the pipe, as in this way the area of the gauze is made sufficiently large to allow the right quantity of air to pass through it.

Gauzes fitted to the air intake of any kind of carbureter should be frequently cleaned. Otherwise they rapidly choke up with oil and dust, the result being that insufficient air passes to the carbureter, which means that the suction on the jet is increased and more gasolene taken to the engine than should be the case, resulting in heavy consumption, boiling water, dirty engine, overheating, and loss of power.

It is often remarked that unless a gauze is fitted the carbureter will choke up. In such a case the fact is overlooked

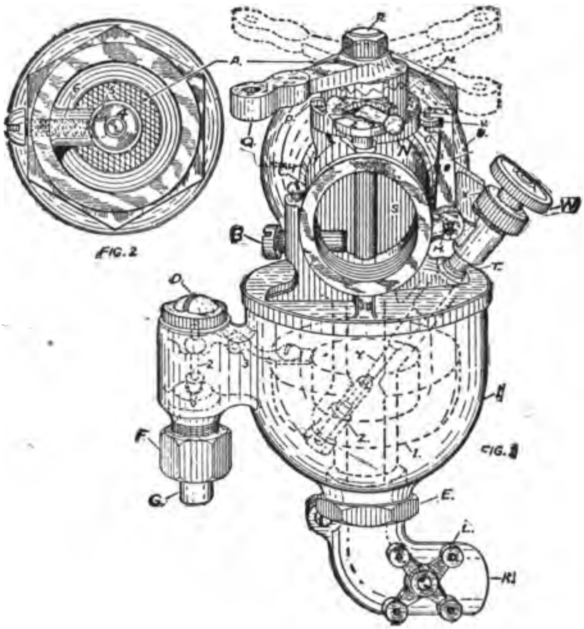
that chokage in a carbureter is due to chokage of the gasolene passage, and not to the air passages, and that dust getting into the carbureter by way of the air intake cannot get into the jet or gasolene passage. As a rule the only damage that dust can do is to get into the engine and pass out through the exhaust valve. While in the engine it can do little harm, though a deposit may be formed on the piston head by it. In one case it appeared to be carbon, in consequence of the bad quality of the lubricating oil. An analysis of the deposit, however, proved that it was caused almost wholly by dust-laden air which was drawn in through the air intake, which was not protected by gauze.

Obviously, the best thing to do is to fit a large gauze, which is detachable, and to keep it clean.

Gauze in the Induction Pipe.

From time to time many experiments have been made with gauze. Occasionally a wire gauze disk is put in the induction pipe, and gauze has been tried in the carbureter. The idea is that the mixture shall be more thoroughly atomized by passing through the fine meshes of the gauze. It may be safely said that the matter is one of experiment, and in some Longuemare carbureters it has been found a really distinct advantage. In this carbureter, the extra air inlet is below the jet, and the air holes are covered by a couple of segments, on the top of which is a perforated brass disk. This disk is just above the jet, and above or below the disk it is very easy to place three or four disks of gauze. Those who know the Longuemare carbureter will understand at once how easily this can be done. It has been found that the effect of the gauze was twofold. It has reduced gasolene consumption, and made it possible to run the engine at a considerably lower speed when desirable; this applies whether the engine is running light or driving the car. The improvement in running appears to be due to the more perfect atomization of the mixture, as the whole of the gasolene and all the additional air have to pass through the gauzes. There

is also a sort of wick effect, as the three or four thicknesses of gauze make a pad immediately above the jet, which is



The Schebler Carbureter—Model H—Section.

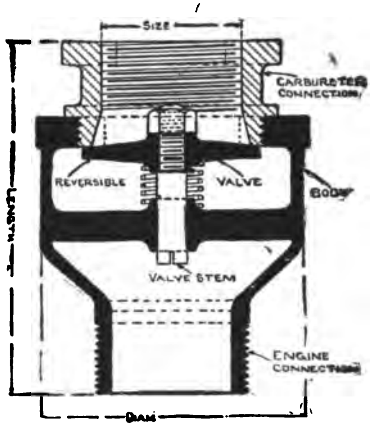
A Compensating air valve complete (4 pcs.)
B Low speed adjusting screw
C Low speed lockscrew
D Float valve cap
E Float chamber lock nut
F Reversible union
G Reversible union nipple
H Lift lever shaft retainer
I Float chamber
J Mixing chamber
K Constant air opening connection
L Butterfly valve starting lever
M Spring cam casting
N Eccentric high speed adjustment
O Cam spring
P Throttle stop
Q Adjus'ble throttle lever casting
R Throttle valve stem
S Throttle valve butterfly disk
T Needle valve retainer
U Needle valve lift lever
V Cam roller
W Needle valve adjusting screw
X Needle valve adjustment retainer
Y Needle valve
1 Float
2 Float valve
3 Float valve lever
4 Air valve adjusting screw
5 Leather friction disk
6 Friction spring

always saturated with gasolene, and seems to afford a small reserve, which results in a better pick-up after slowing on the

throttle. It is obvious that the gauze must have a wire-drawing effect, and thereby put a certain amount of negative work upon the engine, but this negative effect is more than nullified by the superior atomization, so that the maximum power and speed of the engine is not reduced in any way, and the advantages of smoother running at low speeds and a quicker pick-up are gained.

The Breeze Carbureter.

The Breeze carbureter is a good example of the modern carbureter, and is therefore fully illustrated herewith. The manufacturers claim that this carbureter is equally adaptable to all engines and that, when adjustments are once properly



The Breeze Carbureter—Check Valve.

made, it will deliver the right kind of mixture to the engine at all speeds at which it will work without change of adjustment.

The special features are stated as follows:

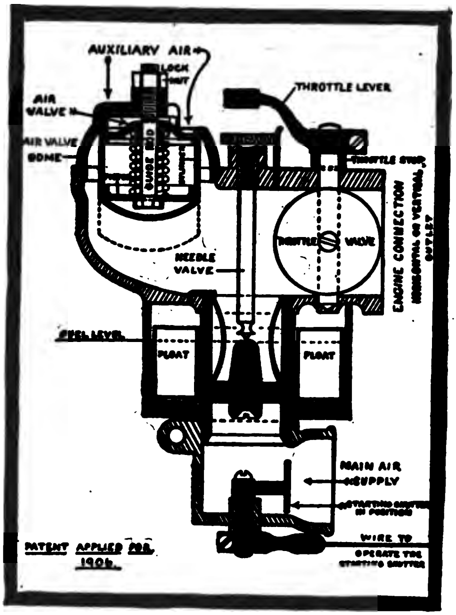
1. Simplicity: all adjustments are independent and when made, stay set.

2. Gasolene and air adjustments both placed on top of the carbureter, the gasolene valve having figures and graduations stamped on a dial head indicating its exact position.

3. Non-fluttering auxiliary air valve maintains an even addition of air to the mixture at high speeds.

4. Central draught for main air and gasolene spray prevents changing of fuel level on grades. The gasolene is always there.

5. Peculiar construction of the needle valve causes the breaking up of the fuel into the smallest particles possible, giving at the same time economy and power.



The Breeze Carbureter, Showing Main Air Supply and Strangling Tubes.

6. Choice of vertical or horizontal, or male or female connection to engine.

7. Carbureter easily detachable from flange of engine pipe connection.

8. Spun brass float, obviating all need of adjusting fuel level, which is a frequent trouble with a cork float.

9. Interchangeable main air tubes giving a wide range of

main air supply and still maintaining the correct cone-shaped air passage.

10. Simple and easily detached hot air attachment.

Principle—The Breeze carbureter consists of a fuel chamber provided with a float feed device to maintain the fuel level always at a point just below the spray nozzle, which is connected by a cross tube to the fuel chamber; when air is sucked through the conical-shaped main air tube by the engine, a proportion of gasolene is drawn up into the engine with it. This proportion is determined by the adjustment of the needle valve. As the suction increases when the throttle is opened or the engine runs faster, the proportion of gasolene taken up is greater than it should be, so the auxiliary air valve is provided and arranged to open against a spring and admit pure air according to the increased suction of the engine. By proper adjustment of this valve spring, it is claimed, the carbureter can be made to furnish a uniform mixture to any engine. A valve or throttle is provided to govern the amount of mixed gas delivered to the engine.

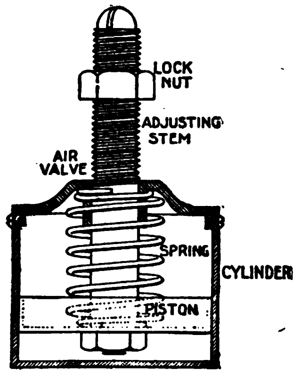
The fineness of the mixture of gasolene and air determines the economy and also the maximum power obtainable from a given size carbureter. A certain minimum of suction is necessary on low engine speeds; and adjustment to make different model engines obtain this is provided by using different sized strangling tubes for the air intake around the spray nozzle.

Auxiliary Air Valve—An auxiliary air valve is provided to furnish the engine with more pure air on medium and high speeds. On low speeds this valve must stay closed and the Venturi tube around the spray nozzle, which the Breeze people have used since 1904, is small enough to keep the suction sufficient to give a good mixture and is automatic within a moderate range of low speeds, but on medium and high speeds the mixture gets too rich in fuel. Fuel is necessary for power, but must have air in the right proportion to burn with it.

The auxiliary air valve is held to its seat by a spring, and the engine suction on medium and high speeds opens it to that

distance which the spring tension permits. This adjustment properly made, the suction of the engine regulates the mixture automatically by pulling the valve open to the proper distance.

To adjust the valve, loosen the air valve adjusting lock nut, turn the slotted stem to the left to stiffen the spring and decrease the air, to the right to weaken it and give more air. Be careful in weakening the spring and giving more air not to weaken it so much that the valve does not seat. Air must



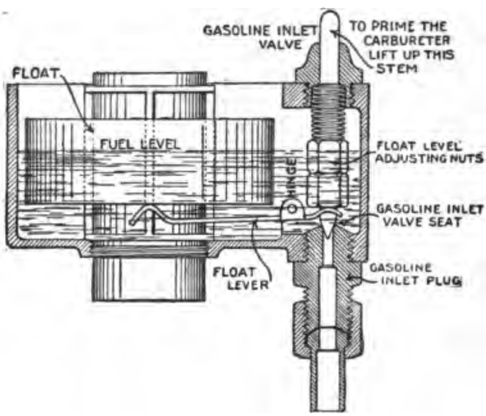
The Breeze Carbureter—Auxiliary Air Valve.

not get in on low speeds or starting will be almost impossible. Lock the adjustment securely.

This device is simple and needs no attention unless both oil and sand get on it at the same time, in which case it will stick and must be cleaned out. Leave all parts dry. Do not oil it. If this happens it would be advisable, for the good of the engine, to protect the carbureter by an apron. The amount of sand required to spoil the working of the air valve would be very bad for the engine if allowed to get to it. No trouble is experienced with the valve under the hood of a touring car. When a carbureter is used where water or dirt are thrown on it, the manufacturers furnish a gauze cage to cover and protect it.

Float Feed Mechanism—When the fuel is at the proper level

the gasolene inlet valve is held down to its seat by its own weight and the spring closes the supply, the float being clear of the float lever. As soon as the level drops the float drops with it, and resting its weight on the long end of the float lever pushes it down and lifts the short end which lifts the gasolene inlet valve and admits more fuel till the float rises clear of the lever again. To raise the fuel level adjust the nuts on the gasolene inlet valve nearer the point of the valve; to lower it, set them further away. Lock them tight after the adjustment is made. The distance from the bottom edge of the adjusting nut to the point of the gasolene inlet valve averages



The Breeze Carbureter—Float Feed Mechanism.

about 5-16 of an inch on a properly adjusted carbureter. **Don't** change the tension of the spring. The fuel level must be properly adjusted on any float feed carbureter. The correct point is usually about 1-16 inch below the tip of the spray nozzle. For an engine with short inlet pipe of large diameter the level may be set a little lower. Keep the level as low as possible. A high fuel level wastes fuel and causes an engine to heat up.

Adjustment of the Breeze Carbureter—Adjustments can always be best made with the muffler cut out or better still the exhaust pipes taken off so that the exhaust from each cylinder

may be observed. If the ignition is right and the compression and valve setting the same on all cylinders the exhausts should all be the same color. The blue flame exhaust is not the best for power, the mixture is too rich. The purple flame is the correct color. A yellow color shows too weak a mixture; black smoke, too much fuel. Too much oil makes the color red.

From three-quarters of a turn to a turn and a quarter is the usual opening of the needle valve required. Screwed all the way down it is closed. To open it turn backward. The correct position can only be determined by experiment. With

Gauze Cage for Exposed Carbureters.

the throttle and spark stationary, the correct position for the needle valve is that at which the engine runs fastest.

Set the needle valve first for low speeds with the throttle nearly closed and the spark on center. Then advance the spark and open the throttle and adjust for high speeds by tightening or loosening the tension of the auxiliary air valve spring.

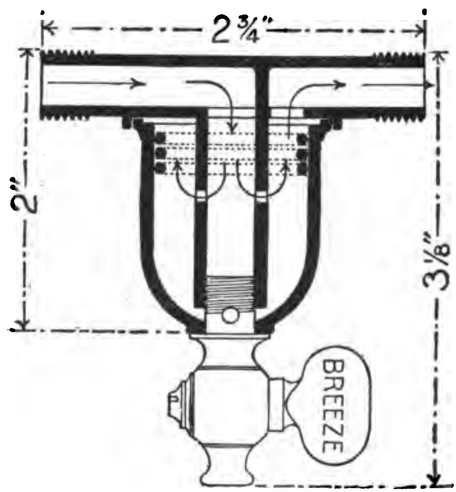
Backfiring is caused by too weak an air-valve spring, dirt in the carbureter, or an insufficient flow to the carbureter. If the auxiliary air valve spring has to be weak, a small strangling tube may be used around the spray nozzle and a large one where the auxiliary air valve spring has to be very strong. A particularly strong spring has to be used with engines of the valve-in-the-head and "T" head types.

Carbureter Troubles.

The following remarks, for which we are indebted to "Carbureters and Engine Troubles," published by the Breeze Carbureter Company, apply to almost all float feed carbureters.

Air valve springs shorten slightly after long use, and adjustment is provided to take up the tension. Imported steel wire for springs, copper plated to prevent rust, stand up longer than the cheap brass wire frequently used.

Dirt getting into the spray nozzle causes backfiring in the



The Breeze Fuel Strainer.

carbureter, and while the engine runs very fast and free on starting it will stop when the clutch is thrown in. The dirt can generally be got rid of by opening the gasolene adjustment a full turn while the engine is running; it is sucked clear through the spray nozzle. Sometimes a larger piece of dirt gets in and acts as a valve, stopping up the nozzle when the throttle is opened. The only plan in this case is to take off the base and clean out the fuel passages. Don't go to this trouble till you are sure that your battery is not weak. The symptoms are often the same.

Irregular running of the engine may be caused by dirt in

the carbureter, sticking float lever or fuel valve, and very often by a nearly broken battery wire, dirty commutator or sticking coil trembler. Speeding up and slowing down under load are generally caused by too small a fuel pipe, insufficient head to the fuel, or dirt or water.

Overheating of the engine may be caused by many things, as insufficient water circulation, improper timing or insufficient lift to exhaust valves. Either too weak or too rich a mixture burns slowly and gives up a larger proportion of heat to the cylinder head and wall than a perfect mixture does. A poor spray overheats, so does poor oil.

Often when a new carbureter is fitted to a car that has been used the complaint is made that as soon as the throttle is opened the engine pounds and knocks and that the symptoms are worse than before. Very likely. The new carbureter probably gives more gas and power than the old one, and of course when combustion chambers and piston heads are carbonized from poor oil or bad mixture, the more gas you put in the cylinder the worse the knock. Take off the cylinder heads and soak them over night in kerosene, clean them thoroughly, and piston heads too, and don't neglect the valve passages. It is not so much the even deposit as the little lumps that stick up that cause the trouble.

Commutators or unevenly timed tremblers on coils sometimes cause trouble. The explosions must take place in each cylinder when the piston is in the same position. If any cylinder is timed too early there will be loss of power, knocking, overheating and possibly a broken crankshaft and always a quicker wearing out of wrist pin and crank pin bearings. A wabbly commutator makes the same trouble.

Missing in one cylinder may be caused by that cylinder having a leak around the valve or valve cage seats, by the inlet valve opening too much and not closing as quickly as the others, or by a valve not seating at all; or, by that cylinder being carbonized. These things cause the engine to take a different mixture. If the cylinders are right the same carbureter adjustment will suit all.

Flooding—Suppose when you turn on the gasolene or stop your engine there is a persistent dropping of gasolene from the bottom of the carbureter. It must be stopped, fuel is being wasted and the mixture spoiled on low speeds.

Don't start in to change the fuel level till you are absolutely sure it is wrong. Flooding when caused by dirt under the fuel valve can often be stopped by lifting the fuel inlet valve and letting the dirt flush through. If this does not stop it the level is most likely too high.

Before readjusting the float level you might take off the base and take out the float and shake it and listen for liquid inside; a leak, though very rare, is possible, and will permit gasolene to get inside and lessen the float's buoyancy. Write or wire for a new one and then return the leaky one for repairs. A temporary repair can often be effected by drying out the gasolene and painting a little shellac over the leak. Don't mistake loose solder in the float for gasolene.

Having tested these points if the trouble is not there, the fuel level is too high and must be adjusted. Shut off the fuel every time you put away a car. It is safest, because there is no float feed mechanism that can always be trusted absolutely, and besides this the lighter part of the fuel keeps evaporating till the bowl of the carbureter is full of too heavy a liquid to make starting next morning as easy as it might be. Always have two shut-off cocks in your gasolene line, one at the carbureter or where you can get at it easily, and the other close to the tank, in case the pipe breaks. Either may save the car some day.

Carbureter Cautions.

Don't try and start with the throttle entirely closed.

Gasolene valves have been known to jar shut.

Remember that "Carbureter knock" may be found in a loose fly-wheel, in loose electrical connections or commutators that ground sometimes in the wrong place.

Don't adjust the carbureter as soon as the engine works badly. There are such things as clogged feed pipes, poor ignition, and exhaust valves that don't seat properly.

Flooding seldom means readjustment of float feed mechanism. Usually there is dirt under the gasolene valve seat or, very rarely, a leaky float.

Don't forget that automatic inlet valves must have a very short lift, and when the engine has more than one cylinder, the springs in these valves must be of an even tension. If these springs are weak or have too much lift, part of the gas will be blown backwards through the carbureter in the compression stroke.

Don't monkey with any carbureter till you have read the maker's book. You may know more about it than he, but you might as well get his ideas on the subject.

Stewart Vacuum Fuel Feed.

There are many disadvantages connected with both the gravity and pressure systems of gasolene supply. With the gravity system it is always difficult to get a sufficient height of liquid above the carbureter, particularly when ascending or descending heavy grades. To get the maximum height of tank over carbureter it is necessary to place both the tank and carbureter in inaccessible places, the tank under the seat or cowl, and the carbureter low down in the hood between the chassis and the engine. With the tank under the seat it is necessary to disturb the occupants of the front seat when refilling.

When the carbureter is located at a low point in the chassis it necessitates the use of a long intake pipe which affects the quality of the mixture to a great extent, especially in cold weather.

With the pressure system an absolutely tight tank is required. Leakage in the upper part of the tank or above the fuel level will reduce the feed of gasolene at the carbureter if it exceeds the capacity of the pump or reducing valve. Excessive pressure will flood the carbureter unless an auxiliary tank is indulged in, and the overflow from the carbureter

greatly increases the danger of fire to say nothing of its effect upon the mixture.

In the vacuum system, the suction of the motor is utilized in lifting the gasolene from the main tank to the carbureter,

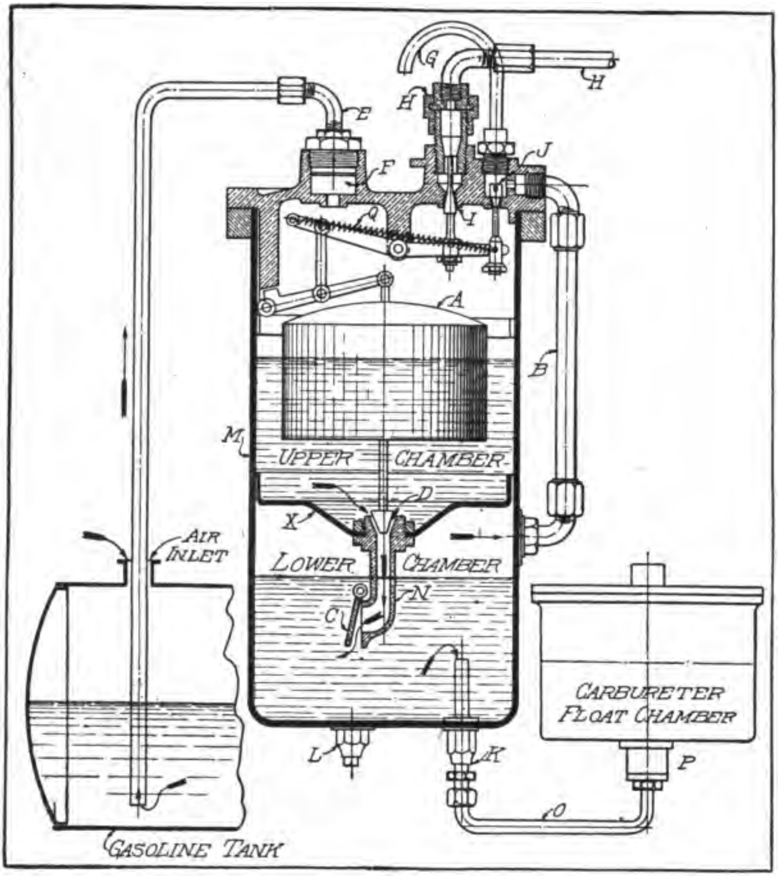


FIG. 4.—STEWART VACUUM FUEL SYSTEM.

the suction being obtained from a connection to the intake manifold. As will be seen from the accompanying figure, this device consists of a vertical tank which is divided into two compartments by a horizontal partition X. The tank is usu-

ally mounted on the front of the dash and under the hood at a considerable height above the carbureter. Being close to the motor there is very little variation between the upper and lower levels when the car is climbing hills.

A metal float A is placed in the upper chamber which maintains a constant level through the lever system and the valves F-I-J and D. The pipe H connected to the motor intake manifold produces a vacuum in the upper compartment or fills chamber when the float A allows the valve I to open, with the atmospheric valve J closed. With a vacuum in the space and the gasolene valve F open, the gasolene is drawn from the supply tank through the feed pipe E and valve F into the upper compartment.

When the required level is reached, the float A closes the fuel valve F and the suction valve I, and opens the atmospheric valve J which allows air to enter the tank and break the vacuum. As the float in rising has by this time opened the valve D in the partition, the lack of vacuum in the upper chamber allows the gasolene to flow into the lower chamber through C. The vacuum which up to this time had been supporting the liquid column in the upper compartment is broken by the air entering through the pipe G and valve J. The lower chamber is kept at atmospheric pressure at all times by air entering through the pipes B and G which pass **above** the valve J.

Gasolene is fed to the carbureter from the lower chamber through the pipe K by gravity. The flap valve C between the two chambers prevents the vacuum from drawing the gasolene in the lower chamber into the upper chamber when the valve D is lifted off the seat. When the lower chamber is filled the action is again repeated, 0.05 gallon being transferred from the main tank at each operation. The action of the valves must be intermittent so that atmospheric pressure can be maintained a part of the time.

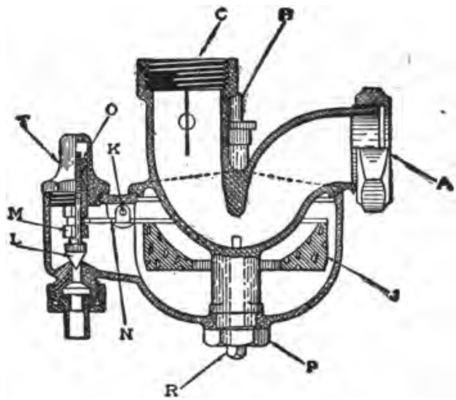
A drain plug L allows the water and dirt collected at the bottom of the tank to be drawn off, the upper extension of the pipe K preventing foreign matter from entering the carbureter. If the car has been standing empty for a time or when it is desired to fill it the first time, the motor is cranked over four or five times with the throttle closed. This will produce enough vacuum to supply the carbureter for starting.

When the vacuum system is used, a tube E runs to the bottom of the main tank. A small vent must be provided in the main tank to allow the gasolene to flow freely to the pipe.

CARBURETER ADJUSTMENTS.

The Holley Carbureter.

In the illustration of the Holley carbureter the adjustable gasolene needle is shown (L). The air enters at A and passes



The Holley Carbureter, Model "W."

down and up through a U-shaped mixing tube. The gasolene enters from the float chamber by an orifice controlled by the adjustable needle. The normal gasolene level is 3/32 inch above the bottom of the U-shaped passage, so that a puddle is formed. Here the air passage is restricted, increasing the velocity of the stream. As the motor speed increases the puddle is gradually swept away and its area diminished, preventing the formation of an over-rich mixture. At the

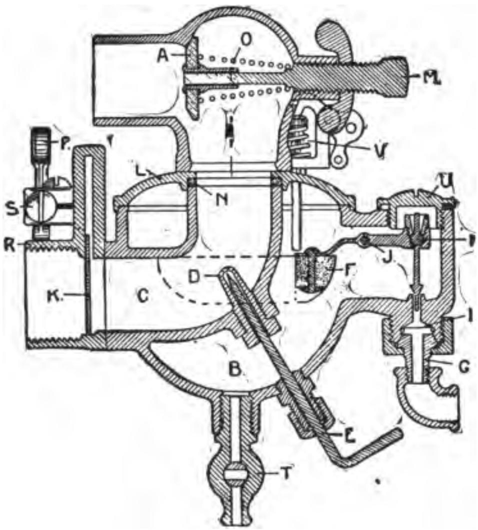
highest speeds the puddle is wiped out and an ordinary spray takes its place. An overflow device prevents flooding.

In operation the gasolene needle is adjusted to a point where the motor runs best, with throttle wide open and spark about center. Next close the throttle to where the motor runs slow enough to suit. If the motor will not run slow, it indicates lack of gasolene because of too low level. If motor runs slow enough with throttle partly closed, but misses upon opening throttle, it indicates too high a gasolene level. To change the level remove the gasolene inlet needle guide cap T and take out the gasolene inlet needle. Hold the weight M by its flat sides (so as not to mar it and cause it to stick) and loosen the taper locknut O. Then by screwing the needle into the weight M the gasolene level is raised in the float chamber; by unscrewing these parts, the level is lowered. One turn of the needle L in the weight M changes the gasolene level about 3/32 inch; one half turn about half, etc. When level is where desired tighten locknut O. Normal level should show puddle about 3/32 inch deep when motor is not running. Conditions may demand this to be altered slightly. R is a sediment plug and has nothing to do with adjustment.

The Schebler Carbureter.

In the Schebler carbureter, of which we illustrate several models, when the motor is running at its minimum speed, the air is drawn through an aperture of fixed dimensions. As the speed is increased, and consequently the flow of gasolene becomes greater, more air is needed and this additional supply is furnished by the compensating air valve A (see illustration of Schebler Model D), which opens more and more as the speed of the engine increases. The compensating air valve, when once adjusted, admits a regulated supply of air in accordance with the degree of vacuum produced by the piston of the motor. In adjusting, the needle valve E should be first closed, and then opened about from five-eighths to three-quarters of a turn. Retard the spark, open the throttle P about one-fourth, so as to equalize the fixed air open-

ing below the compensating air valve A. Start the motor and adjust the needle valve E until the motor runs smoothly and without back firing or missing. Now open the throttle P wide, keeping the spark retarded, and by turning the air valve adjusting screw M increase or weaken the tension on the



The Schebler Carbureter—Model D—Section.

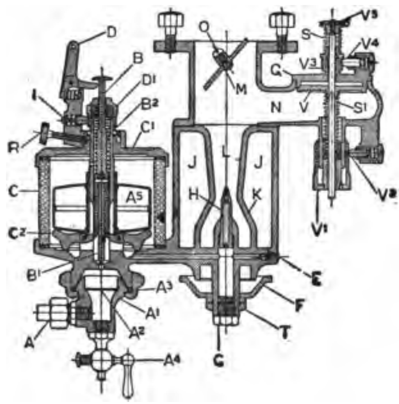
A Compensating air valve	**L Float chamber cover**
B Float chamber	**M Air valve adjusting screw**
C Mixing chamber	**N Cork gasket**
D Spraying nozzle	**O Air valve spring**
E Needle valve	**P Throttle lever**
F Float	**R Pipe connection**
G Reversible union	**S Throttle stop**
H Float valve	**T Drain cock**
I Float connection	**U Float valve cap**
J Float hinge	**V Flushing pin**
K Throttle	

air valve spring O until the proper mixture is obtained. If the mixture is too rich, the tension of the spring O should be weakened, permitting more air to enter the carbureter; should the mixture be too weak, the tension of the spring should be increased.

Schebler carbureters are made of brass, but aluminum is furnished on special orders. The bowl design combines compactness with practicability, serving for reservoir as well as having the float chamber embodied therein. The float is made of cork, heavily shellaced and hinged as shown in the sectional view, letter J. The size of the gasolene valve is much larger than ordinarily used. Gasolene is supplied through a reversible union which permits the feed pipe to run in any direction desired.

The Stromberg Carbureters.

Many well-known machines are fitted with the Stromberg type carbureters, of which we illustrate two examples in section, namely Types A and B.



Stromberg Carbureter—Type A—Section.

The following are the methods of adjusting these carbureters:

How to Adjust Stromberg Type A.—After the carbureter is installed turn on the gasolene, and note if the level of the gasolene in the float chamber is opposite the mark or line cut on the outside of water jacket opposite float chamber. By turning the adjusting nut D-1 up or down you can raise or lower the gasolene level so that it will be opposite the

line. Do this before starting the engine. Next see that the valve V seats lightly by tapping the nut V-5 lightly with the forefinger. If it does not seat, turn up adjusting lock V-1, or if too tight, turn down V-1. See that adjusting locknut V-3 is turned down as low as possible. Next prime the motor by lifting the needle valve B until float chamber is filled. You will notice that gasolene drops into the adjustable air cup F. This cup should be adjusted in this manner: Turn up the air cup F until it is tight, then turn it down one or two turns, possibly three, according to the motor. On the average motor this will admit the proper amount of air which regulates the gasolene supply. If you are getting too much gasolene, turn the cup up, if too little, turn it down.

Next start the motor and adjust the low speed adjusting nut V-1 with both the throttle and the spark retarded. The spring S-1 is used to seat the valve V, and if the mixture is too rare and engine back fires, turn up nut V-1 until the motor runs smoothly. Next advance the spark and open the throttle gradually until it is wide open, and if the motor back fires, turn up the high speed adjusting nut V-3 one notch at a time until the motor runs smoothly without back firing. Remember that the valve spring S simply controls the valve V on open throttle or high speed, and should not be in contact with nut V-5 when motor is at rest. The seating of valve V is entirely controlled by spring S-1. There should be a space between the nut V-5 and spring S of about 1-32 inch and not over 1-8 inch, according to the motor.

In very hot weather shut the water off when the carbureter gets too hot. If the water is drawn from the radiator of the car, either to clean same or in laying car up for the winter, be sure and disconnect the water pipe connections to the water jacket on the carbureter at J-2, so that the water jacket will also be drained. It may be that in adjusting the nut V-3, which is called the high-speed adjusting nut, to stop motor back firing you will have to turn up nut V-1 one or two notches, but after doing so be sure to see that the motor runs smoothly on closed throttle.

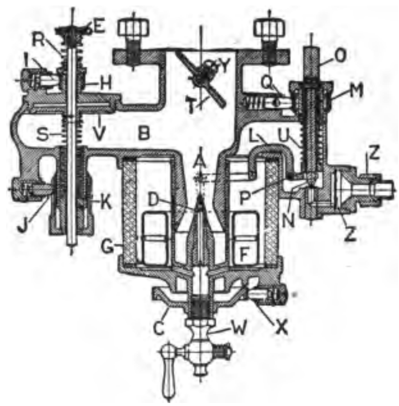
The motor uses just enough gasolene to keep it going on low speed, and as it increases in speed it takes automatically the quantity of gasolene which is necessary. The suction created by the motor draws air in through the fixed air opening between the adjustable air cup F and the bottom of the water jacket passes up through the mixing chamber L past the spraying nozzle H and in passing sucks the gasolene out of the nozzle in a canopy-shaped spray. This mixture is then joined by the air coming through the valve V, which creates a perfect mixture. The more air that comes in through the adjustable air cup and the less through the valve the richer the mixture will be and vice versa, so do not have your spring S-1 too tight.

How to Find Proper Nozzle Size—If after you have adjusted the auxiliary air valve according to instructions, the mixture is still too rich, adjust valve V until it is off its seat, then adjust locknut V-3 down as far as it will go, and if the mixture is still too rich, it is conclusive proof that the nozzle in the carbureter is too large. If the motor misses on high speed on normal adjustments, tighten up on valve V by turning up the nut V-3 and nut V-1. If these springs are then too tight to get proper mixture, put in a smaller nozzle. To change the nozzle H, remove the plug G, then take out nozzle with an ordinary screwdriver.

How to Adjust Stromberg Type B—Type B differs from Type A in being made without the water jacket and is concentric, having the float chamber built around the mixing chamber.

After the carbureter is installed turn on the gasolene, and note if the level of the gasolene in the float chamber is 15-16 inch from the rim on the bottom which holds the glass. By turning the adjusting nut M up or down you can raise or lower the gasolene level. See that the level is right before starting the engine. Next see that valve V seats lightly by tapping the nut E lightly with the forefinger. If it does not seat turn up adjusting nut K, or if too tight, turn down K. See that adjusting locknut H is turned down as low as pos-

sible. Next prime the motor by lifting needle valve O until float chamber is filled. You will notice that gasolene drops into the adjustable air cup C. This cup should be adjusted in this manner: Turn up the air cup C until it is tight, then turn it down two full turns. On the average motor this will admit the proper amount of air which regulates the gasolene supply. If you are getting too much gasolene, turn the cup up, if too little, turn it down. Next start the motor and adjust the low-speed adjusting nut K with both the throttle and the spark retarded. The spring S is used to seat the



Stromberg Carbureter—Type B—Section.

valve V, and if the mixture is too rare and engine back fires, turn up nut K until the motor runs smoothly. Next advance the spark and open the throttle gradually until it is wide open, and if the motor back fires, turn up the high-speed adjusting nut H one notch at a time until the motor runs without back firing. Remember that the valve spring R simply controls the valve V on open throttle or high speed, and should not be in contact with nut E when motor is at rest. The seating of valve V is entirely controlled by spring S. There should be a space between the nut E and spring R of about 1-32 inch and not over 1-8 inch according to the motor. It may be that in adjusting the nut H, which is called the high-speed ad-

justing nut, to stop motor back firing you will have to turn up nut K one or two notches, but after doing this be sure to see that the motor runs smoothly on closed throttle.

The motor uses just enough gasolene to keep it going on low speed, and as it increases in speed it takes automatically the quantity of gasolene which is necessary. The suction created by the motor draws air in through the fixed air opening between the adjustable air cup C, and the bottom of the gasolene chamber, passes up through the mixing chamber A past the spraying nozzle D, and in passing sucks the gasolene out of the nozzle in a canopy-shaped spray. This mixture is then joined by the air coming through the valve V, which produces a perfect mixture. The more air that comes in through the adjustable air cup, and the less through the valve the richer the mixture will be and vice versa, so do not have your spring S too tight. To change the nozzle D, remove the drain cock, then take out nozzle with screwdriver.

Carbureter, Alcohol—Carbureters for the use of denatured alcohol instead of gasolene in internal combustion engines are now successfully in operation. Experiments have also been made in the use of alcohol with acetylene. In this case the alcohol mixture is passed through a wire gauze containing calcium carbide and the water contained in the mixture acts upon the carbide and produces acetylene gas. Another type of alchohol carbureter is used with alcohol and gasolene, the engine being started with gasolene and running with alcohol as soon as the carbureter is sufficiently heated. Heat is invariably required for the complete vaporization of alcohol.

CHAPTER VIII

DRIVING FORD CARS AND TRUCKS

Probably one of the most important features of running a Ford car is that of fuel economy, and with this idea in view will take up the subject of carbureter adjustments before entering into the other items, such as ignition, that contribute so greatly to the efficiency of the car. As with any other car, the greatest fuel efficiency is attained by properly mixing and proportioning the gasolene vapor and air for any particular load or atmospheric condition.

When the Ford is equipped with a Holley carbureter, the only point of adjustment is that of the needle valve that controls the flow through the spraying nozzle. This must be adjusted, of course, so that the amount of gasolene passed is just as little as will meet the power requirements at that particular moment. As this maximum amount of power varies from time to time owing to differences in grades and road conditions, it is evident that the mixture would have to be adjusted continually for the most economical results. Unfortunately such continuous adjustment is practically impossible so that the best we can do is to effect a compromise between the maximum and minimum demands for normal running and make the temporary adjustment when striking a steep grade or heavy road. Owing to the method of installing the carbureter control, the adjustment of the needle valve for varying conditions is not as difficult as the foregoing might lead one to believe, and very good results may be obtained with but comparatively little attention.

A long rod leading from the carbureter nozzle valve to the

dashboard terminates in a brass button within reach of the driver's side of the dashboard. By turning the button in one direction or the other it is possible to open or close the needle valve and vary the amount of gasolene. The gasolene valve button should be turned clockwise as far as possible (closing needle valve) without loss of power, since this gives the most dilute mixture possible. The position marked by the maker for the normal driving position is really the position for maximum engine power and is therefore not the proper one for level road driving, since under the latter conditions the mixture is by far too rich. To facilitate frequent changes in the mixture several devices have been placed on the market which bring the control from its present awkward position to a point either on the steering wheel or near at hand. This is a great convenience and is well worth installing, since by manipulating through one of these attachments, several owners have obtained as high as 40 miles per gallon.

With the mixture too weak, the engine will lose speed and power, this being generally accompanied by carbureter "popping" or firing back through the carbureter inlet. This is not only disagreeable, but is dangerous, since the discharge through the carbureter is liable to set fire to the car, especially if the carbureter drips or overflows to any extent. Back-firing can be cured by opening the needle valve to increase the richness of the mixture. An overly advanced spark will also cause back-firing occasionally with a proper mixture, so that if the correction in mixture does not stop the trouble, try readjusting the spark.

In regard to the proper running point for the spark it can be said that the most economical position will be found when advanced just short of the position in which knocking begins. If much retarded from this position, the engine will heat rapidly, lose power, and increase the fuel consumption for equal speeds. If advanced to, and held on, the point where knocking continues, there will be rapid wear and liability of damage to the bearings and crankshaft. When up to required speed run up to knocking point, and then slightly

retard until knocking ceases. For other points in regard to the Ford ignition system consult matter under the heading, "Missing and Knocking."

Starting Ford Motor.

Starting trouble with the Ford motor may be caused by a poor mixture, ignition trouble or by trouble within the motor proper, but with a car in fairly good condition it usually can be traced to the mixture. At least this should be the point on which to base future operations, since the alterations are more easily and surely made with the carbureter than with the ignition system or motor.

First note the position of the V-shaped nick on the nozzle adjustment button on dash at which the motor develops its maximum power on the level. Say this points towards the front of the car. With a cold motor turn the button one-half revolution toward the left, open the throttle to about the 20-mile per hour position, and either fully retard the spark or place the lever within two or three notches of its furtherest back position. Leave switch open, and turn over engine 4½ revolutions, the valve in the carbureter intake being held closed during this period by means of the wire control. The wire pulled fully out will fill the cylinders with a rich mixture due to the heavy suction in the mixing chamber. Switch on the current, let go of the intake valve wire, and give a quick up-turn on the starting handle. This should fire the motor. If motor does not start give two or three more quick up-pulls on starting crank, without using the air inlet valve wire. Too frequent use of the air valve is likely to flood motor and cause additional delay. If motor still does not start examine the ignition system, especially the vibrators on the spark coil.

With the engine firing, partially close the throttle valve lever on wheel, and slowly turn back notch on nozzle adjustment button until it is again in the normal running position. When starting the motor it is a safe plan to put on the brakes so that the car will not start to crawl forward when the

engine starts through the stiffness of the cold oil in the transmission.

In starting a warm engine, the mixture must be lean rather than rich, this requiring a different adjustment of the needle valve button. The air valve wire should not be used, as the chances are that the mixture is already too rich. Place the nozzle control button in the normal running position (toward dash in above example), throw in switch and turn engine over. If it fails to start firing, turn nozzle button about one-half revolution, or until needle valve is nearly closed, and pump engine over several revolutions to get rid of the rich gas, the switch being in the off position. Now turn needle valve button back to normal running position once more, close switch, and give short, sharp pull on starting crank. Engine should start.

See that the spark coil vibrator blades are adjusted as lightly as possible, and when engine is running, turn off contact screws until a cylinder stops firing. Now run screw in again until motor again fires and give an additional turn of about one-eighth revolution. See special note for other ignition adjustments.

Before turning the motor over be sure that the spark is well retarded, despite the fact that almost any engine starts better with the spark advanced. A savage back-kick from the starting handle due to an advanced spark is usually very successful in mashing the small bones of the wrist and is capable of even more severe and lasting injury. An acquaintance of the writer was jerked down suddenly by his starting crank in such a way that his chin struck the radiator cap. As he happened to have his tongue between his teeth he is now minus a greater part of that useful organ of speech and can also exhibit two beautiful five-tooth bridges—upper and lower. Two months after the accident he had the plaster cast removed from his right wrist.

"Retard When Cranking."

In addition to the dangers mentioned above, an advanced spark is likely to cause back-firing through the carbureter when being cranked. This is due to the motor being turned backward so that the burning gas in the cylinder passes out through the inlet valve and into the carbureter. If the carbureter has been recently flooded or if the float valve is leaky, causing the gasolene to overflow, there will be danger setting fire to the car. Starting a cold motor with a weak mixture often causes the same trouble.

When trouble is experienced in starting the motor when it is hot or well warmed up, the cause is usually due to a rich mixture. If partially closing the needle valve or carbureter does not stop the trouble it is likely that the gasolene level is too high in the float chamber and nozzle. In the Model "T" Ford, the gasolene level should be so that the little tube inside the carbureter should just touch the gasolene in the well.

Ford Speed Changing.

Speed changing on the Ford is accomplished by two pedals and a side lever, a third pedal located on the footboard being the brake. All three of the controls act directly on the transmission sheaves by means of two brake bands and a clutch. The transmission is of the planetary type in which the gears are always in mesh, the first speed and reverse being geared while the high is a direct driven speed produced by locking all of the gears into a unit mass.

To obtain the first speed, the clutch pedal "C" is pressed slightly to hold the gears in neutral and the side lever is pushed forward. The clutch pedal "C" is now pushed as far forward as possible and is held there until the car accelerates on the first speed for about 50 feet, or until it reaches a speed of about 7 miles per hour. It is now thrown into second speed or "high" by releasing the clutch pedal and allowing it to

return the entire distance toward the driver. To reverse, it must be first brought to a stop, and the side lever brought back to a vertical position. By depressing the reverse pedal (R) the car will be brought into reverse. The car may also be reversed by depressing the clutch pedal (C) half way and then the reverse pedal (R).

For first and second speed, the lever should be as far forward as possible, while for reverse it should be vertical.

To secure a smooth change with the Ford transmission, it is necessary after speeding up on first gear, say to 6 miles per hour, to close the throttle as the foot comes back into position for high speed. The proper condition being that the engine has not slowed down appreciably when the high speed clutch engages and the first speed band disengages. If the throttle is closed too much, there will be a jerk due to the road wheels accelerating the engine. If the throttle is not closed enough, there will be a jerk due to the engine speed being checked by the application of the clutch. This can only be perfected by practice. A worn clutch band is the cause of much jerking and even with the most careful manipulation of pedal and throttle it will often skid the wheels.

If the low engages in a jerky manner, if the car climbs hills badly, or if the motor seems to run faster than it should when in low gear, it is likely that low speed brake band needs relining. When engaging the low speed, the pedal should be brought down smoothly and firmly and as soon as gear is engaged the pedal should be held so that there is no slipping and wear on the drum or band. As the reverse is seldom used it can be used for a brake to distribute the wear, but it should not be used to make a full stop as it is likely to stall the motor. As far as possible, coast to a stop.

Breaking in a Ford Car.

In starting a Ford for the first time, the chief point to bear in mind is that excessive speed, if long continued, will be certain to lead to trouble. If it is driven at an average

speed of 20 miles per hour it will last for years, but if driven at 30 miles its life may be counted in months, especially when a good share of the work is performed on country roads. During the first 500 miles of its life one should be particularly careful to avoid over-driving, although the temptation to try out a new car is almost irresistable. The new parts are as yet unaccustomed to one another, the bearings are stiff and likely to overheat and the piston rings are not yet thoroughly adapted to the cylinder bore. It takes a little time for the parts to "sweeten" and for the shafts to burnish the bearing surfaces.

When started off on hard work from the very beginning the tiny rough spots cause a great friction which appears in the form of heat. The heat thus produced causes the parts to expand, thus still further increasing the tightness of the bearings. In the end this will either result in scoring the surfaces or seizing in extreme cases. As the coefficient of friction in an old bearing is much lower than in a new, the heat is developed more slowly and the scoring is less likely. Again, in the new, tight bearings, the oil does not flow over the surfaces as readily as in an old bearing.

It is not advisable to drive faster than 20 miles per hour during the first 500 miles, and the average speed should be preferably less than this, say 15 to 18 miles.

Ford Oiling Troubles.

Usually the front cylinder of a Ford motor gets too much oil, causing the plug in that cylinder to soot rapidly and cause misfiring. The remedy is to cut down the oil until it is not high enough in the flywheel reservoir to run out of the upper test cock but just high enough to run out of the lower. Avoid using too little oil in your endeavor to correct this fault; the exact amount is best taught by daily observation. The oil supply pipe runs forward through the crank case delivering the oil near the front cylinder so that the front is the first to suffer in case of an excess of oil in the reservoir.

Sooting of the plugs due to an excess of oil may also be

due to the enclosing of the valve stems by the side plate. Any wear in the valve stem holes will cause oil to be drawn up and into the cylinders and on the plugs. Removal of the cover plate will stop this annoyance.

Overheating.

Obstructions in the cooling system such as deposits of lime from hard water, a shred of rubber broken free from the hose, or air-bound connections, will cause overheating. A retarded spark with the throttle fully opened or a defective timer spring will also cause the trouble. Restricted lubrication or tight bearings are often accountable. An excessively rich mixture delays combustion and transmits a great amount of heat to the jacket water.

The radiator should be tested by placing the hand at various points to see if the heat is uniformly distributed. If it is cool in spots it is evident that the radiator is clogged at some point. Examine the hose and connections carefully for deposits or for loosened layers of rubber. When driving at a fair speed keep the spark well advanced, nearly to the knocking point; never let the spark be retarded with the throttle opened to any extent.

Leakage past the piston rings due to bad rings or to an uneven, wavy cylinder bore allows the hot, burning gas to sweep the oil from the cylinder walls, increases the friction and hence the heat. Any considerable amount of the gas passing the piston rings also increases the radiating surface and the heat transmitted to the jacket water.

Leakage of water past the cylinder head gasket produces steam in the cylinder which in turn destroys the oil film between the piston and the cylinder walls. When the oil film is once destroyed, the increased friction causes heat and trouble with the cooling system.

In some cases, overheating has been caused by covering the radiating face of the radiator with large license tags or signs. Fully closing a radiator cover, used for protection in winter,

will also cause the same trouble. See that the license numbers do not keep the air from freely entering the radiator, especially in hot weather.

A broken or loose fan belt will cause the motor to overheat, especially when standing idle. Sediment or gummy deposits from anti-freezing solutions clog up the cooling system. See that the cylinder head gaskets do not obstruct the flow of water from the cylinder casting to the cylinder head.

Missing and Knocking.

Missing and jerking of a Ford car may be due to a variety of causes, a poor mixture, irregular ignition, or trouble in the motor proper. Sooted plugs, especially the plug in the front cylinder, may cause the missing due to an excess of oil (see Oiling Troubles). A wabbling or dirty timer will cause the same trouble, as will sticking vibrator points on the spark coil. Broken insulation on the wires, broken spark plug porcelains, weak batteries or magneto trouble, are also causes of misfiring.

On old cars, misfiring is frequently caused by worn valve stem guides admitting air into the manifold and ports. This air of course dilutes the mixture and causes the greatest difference when the throttle is well closed and when the suction is the greatest. The effect due to air leaks is the least at high speeds, as the suction is less and the requirements for a lean mixture are greater than at low speed. A motor in this condition does not idle well. Misfiring will usually produce knocking.

Another source of knock in a Ford is that of the cylinder head, which by projecting into the bore intermittently comes into contact with the piston. The knock produced by a loose crankshaft is more pronounced on a heavy pull or when running at about 15 miles per hour. At higher speeds the blows are so rapid that the noise disappears. Knocks due to loose connecting rods and piston pins are more noticeable when the

load is suddenly released or when idling. The knock due to the piston striking the cylinder head is regular and is practically of the same intensity at all times.

The cylinder head gasket should be installed with the pistons of cylinder 1 and 4 projecting. Now lay gasket brass side up so that it clears both pistons by a sufficient distance to prevent it from touching when squeezed out by the pressure of the bolts. Now lay the cylinder head in position, making sure that the bolt holes are clear of any accumulation. Insert all bolts about half-way and move the head so that it will clear all pistons when the engine is turned over by hand. Any dirt in the bolt holes will cause the head to shift so that it will be struck at the upper end of the piston stroke.

Oftentimes it will be found that the knock is not in the motor at all, but is due to a broken tooth in the driving gear, or to play in the universal. Both these troubles often sound as if they were located in the motor.

Care of Ford Running Gear.

Once every month, the front and rear axles, bushings in spring hangers, steering knuckles, and hub bearings, should be inspected and lubricated. See that the nuts and cotter pins are all in place and that the spring clips which fasten the springs to the frame are in proper condition. To remove the front axle jack up front end of car, disconnect steering gear, radius rods at ball joints, and the two cotter-pinned bolts from shackle on each side, thus releasing front spring.

If the axle or spindle should be bent care must be taken in straightening, as the work must be done cold to prevent drawing the temper. It is better to return them to the factory for this repair. It is essential that the wheels line up since excessive tire wear will result from poor alignment. The wheels should be jacked up and tested periodically for looseness and side play. If a sharp click occurs now and then in spinning the wheel and the wheel is momentarily checked, it is likely that there is a split or cracked ball. This should be

removed, for in time it will destroy the entire bearing. A wheel in perfect adjustment, after spinning, should come to rest with the tire valve directly below the hub.

Speeding a Ford.

While the Ford is not primarily built for speed, it can be "doped up" so that the results obtained will be rather surprising to those who have only driven stock models. The increased speed it should be remembered greatly shortens the life of the car, and the changes suggested herein should only be attempted when a good money prize or other consideration is offered that will offset the expense of the change and the depreciation of the car.

The first thing to attend to is the reduction of weight and wind resistance, this being accomplished by removing unnecessary parts, such as the body, top, windshield, fenders and running boards. A low racing body with bucket seats can then be obtained from any dealer in Ford supplies and fitted to the chassis. These can be had at so low a price that it does not pay to make them. The steering wheel can now be lowered to fit the new driving seat. At this point we wish to remark that unless the future racing man is a good mechanic he had better add at least one automobile garage man to his payroll for some of these alterations require considerable experience and skill. Changing the steering column requires tools and a knowledge of automobile detail.

More power is required and therefore the compression must be increased. This is generally accomplished by planing down the top of the cylinder head by about one-eighth inch so that the volume of the combustion chamber is diminished and the compression raised to approximately 60 pounds per square inch. For this operation the motor must be removed from the chassis. The valve timing must be changed to meet the increased motor speed, and the lift of the cams increased to allow the charge to enter more freely and the exhaust to leave without back pressure.

In regard to the timing, it is practically impossible to give any definite instructions except that exhaust and inlet valves must both open earlier, and the inlet must stay open longer. The exact amounts by which these alterations are made are usually a matter of individual experiment since it is seldom that two motors will perform in exactly the same way. The old camshaft must be removed and a new one installed, preferably with separate cams. By using separate cams keyed on the shaft it is easier to make changes in the timing than when integral cams are used; at least they are preferable during the experimental period. After the best arrangement has been found, a new integral camshaft can be made to correspond with the experimental camshaft. To increase the lift of the valves, the peak height of the cams must be increased by approximately one-eighth inch.

To insure prompt closing the weight of the valves should be decreased as far as commensurate with safety, and the tension of the valve springs should be increased. The muffler and old exhaust pipe must be removed and replaced by short pipe nipples that just reach beyond the hood, one nipple for each cylinder. If the nipples are of "L" form with the open ends pointed toward the back of the car, the scavenging effect on the exhaust gases will be increased and the suction created will be an aid to the entering mixture under certain conditions of valve timing.

As the motor will run much faster under racing conditions, it is advisable that the ignition be changed, or at least the arrangement of the commutator. The short segments and the increased electrical resistance due to the higher magneto frequency will cut down the primary current at the high speed that we expect to attain. Either a high tension magneto, or a battery system similar to the Atwater-Kent will act well at high speed. In any event, a master vibrator should be used if the old coils are to be used.

Owing to the increased compression and higher speed it will be necessary to carefully lap in the rings and weigh all of the pistons. In some cases it is desirable to use the new

form of high compression rings. If all of the pistons are not of the same weight they must be cut down or new ones obtained in order to reduce vibration at high speed. The new aluminum alloy pistons are just the thing for this purpose for they reduce the vibration and the bearing pressures due to inertia. Balance the connecting rods in the same way.

Next, we must pay attention to the lubrication system and increase the amount of oil fed to the bearings by increasing the size of the oil pipe inside of the crank case. Holes are cut in this pipe opposite to each connecting rod, and a hand oil pump is added for forcing oil into the crank case. The main and connecting rod bearings are grooved for a better distribution of oil over the bearing surfaces.

It is necessary to change the rear axle gearing to obtain a higher gear ratio between the motor and road wheels. Racing gears for Ford cars can be obtained from specialty dealers which are interchangeable with the stock gears, making it an easy matter to install them. Oversize tires, 31x4 inches, are more durable under racing conditions than the stock 30x3½ used on the rear wheels.

To make the car hold the road better, shock absorbers of the usual Ford type should be fitted. Wire wheels in place of the stock wheels are lighter, stronger and easier on the tires. A letter recently written to **"Motor Age"** states that the inlet and exhaust manifolds were increased to 1⅛ inches in bore and that a 1¼-inch Schebler carbureter was used. The cylinders were bored oversize, and a gear ratio of 3 to 1 was used. In answer to this letter the editor of the Reader's Clearing House proposes the following timing for a racing Ford:

Inlet opens 5 degrees after upper dead center.

Inlet closes 50 degrees past lower dead center.

Exhaust opens 42 degrees before lower dead center.

Exhaust closes 5 degrees after upper dead center.

This he claims is only a basis on which to begin experimental work, as the exact value will differ in individual cars. The car described by the contributor gave 69 miles per hour on a one-half mile speedway.

Ford Car Speed Changing.

In coming down from high to slow speed on a hill do not let the engine race. Close the throttle just before you push the pedal forward, so that when you reach free-engine point the engine will be only just comfortably turning over. Engage slow speed, and then gradually open the throttle as far as is necessary to carry you comfortably on. Do not try to rush a hill on slow speed. If you race the engine between high and slow speed, you will engage slow speed with a jerk that will mean discomfort for all in the car—to say nothing of the engine itself.

In picking up high speed you let the pedal come back from slow, close the throttle a little, and the clutch will then take hold "sweetly." You ought not to jump forward with a bound. If there is the slightest disinclination on the part of the clutch to take up the load, slip it, by pressing the clutch pedal slightly forward again, going right forward into low speed once more, if both car and engine have lost most of their momentum. It ought to shock your mechanical sense to feel the engine laboring in the effort to pick up the clutch. Another point—not so important. Retard the spark slightly when picking up the high speed, advancing it as you get way on.

CHAPTER IX

IGNITION—MAGNETOS—SELF-STARTERS

In Fig. 1 is shown a perspective view of a typical true high-tension type magneto, the magnets and pole pieces being omitted for the sake of simplifying the drawing. The armature lies between the pole pieces and magnets in the same manner as in the elementary magneto previously described. At the right of the perspective is a section through the armature showing the actual arrangements of the two windings on the armature, the winding in the perspective being simply diagrammatic. The shuttle armature of "H" form is indicated by H in both views.

This armature is connected to the shafts D and N by two brass end plates similar to F. The body of the armature in general is built up of a laminated sheet steel to prevent the generation of useless eddy currents and to increase the strength of the magnetic flux through the armature winding. The primary winding is grounded to the armature core at the point Y, and is then given several turns around the iron core K, the outer end of the winding being connected to the connection bolt 2B at the point M. It should be remembered that the primary winding consists of a few turns of heavy wire.

From the point M, the secondary winding consisting of thousands of turns of very fine wire is started. The inner end of the secondary being connected to M makes the secondary simply a continuation of the primary winding. This is not shown in the perspective as it would greatly complicate the drawing, but the true arrangement can be easily seen from the section at the right in which J is the primary and L is the secondary, an insulating strip G separating the two parts of the circuit. The entire series of winding is insulated

from the core by the insulation indicated by the heavy black lines. A band I binds the wire against the centrifugal force that tends to burst the winding when the armature is rotating.

Primary current is carried to the circuit breaker jaw 2A

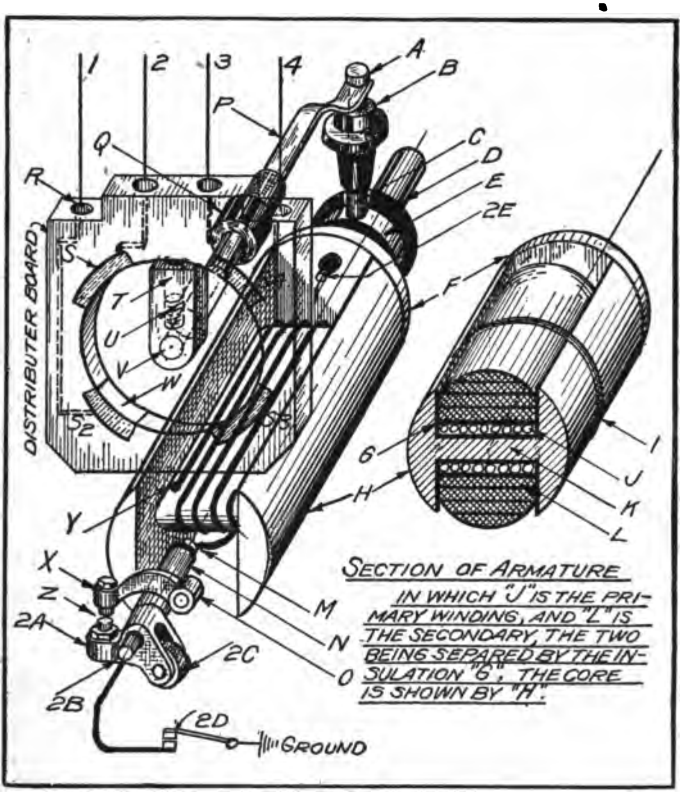


FIG. 1.—TYPICAL TRUE HIGH TENSION TYPE MAGNETO SHOWING CONSTRUCTION AND CIRCUIT IN DIAGRAMMATIC FORM.

and the switch 2D, through the insulated connection bolt 2B, which is insulated from the shaft N by the black insulation shown. The outer end of the high-tension winding is carried to the high-tension collector ring E by means of the insulated pin 2E. A brush at 2B carries primary current to the

grounding switch 2D, which when closed grounds the primary and stops the generation of high-tension current. This switch is generally placed on the dash of the automobile.

A primary circuit breaker jaw 2A, which is connected to the primary winding, and is insulated from the shaft, revolves with the shaft and makes intermittent contact with the jaw X at the point Z. The jaw X is grounded to the shaft and revolves with it so that the two contact points are always opposite to one another. Every time that contact is made between the two jaws at Z, the primary circuit is completed through the ground. The opening and closing of the jaws is accomplished by means of a stationary cam which acts on the cam roller 2C, the contact between the cam and roller being made twice per revolution.

When the contact is broken, the primary circuit is opened, which gives a heavy current impulse to the secondary winding, this impulse resulting in a spark at the plugs. The spark therefore occurs at the instant when the breaker opens the circuit. The cam that opens the jaws is usually made of fiber board, and is located in the breaker housing that covers the mechanism. In some types of magnetos the cam revolves against stationary breaker jaws, but this is merely a matter of detail and in no way affects the principle of operation. The contact points Z are either of platinum-iridium or of metallic tungsten.

By shifting the breaker housing to the right or left by means of lever, the breaker jaws open sooner or later in the revolution of the armature, causing the advance or retard of the spark. This is similar to the effect produced by rocking the housing of the battery timer.

A distributor board is shown in the perspective which contains the metal sectors S-S2-S3-S4, each of these sectors being connected to the wires 1-2-3-4, which lead to the spark plugs in the cylinders. These sectors receive high-tension current from the brush T contained in the revolving distributer arm V, each sector being charged in turn as the arm

revolves. The distributer board is of course built of some high insulating material such as hard rubber or Bakelite, and is shown as if it were transparent so that the armature parts may be clearly seen. A spring U forces the brush into contact with the sectors and also electrically connects the brush with the high-tension current coming through the connector shaft V and the second high-tension brush holder Q.

High-tension current from the secondary winding passes from the connection 2E to the collector ring E, this ring being thoroughly insulated from the frame by the hard rubber bushing D, shown in solid black. The high-tension current is taken from the collector ring by the brush C, through the insulating support B, and to the terminal A. From A the current passes through the bridge P to the distributer arm U through the brush holder Q and the connector V.

The current passes to the plugs through 1-2-3-4, and the plugs being grounded, the current returns through the grounded frame to the armature coil through the arms X and 2A at the moment of contact.

The distributer arm V is driven through a gear (not shown) from a pinion on the armature shaft N. With four-cylinder motors the distributer travels at camshaft speed or at one-half of the armature speed, since the armature of a four-cylinder motor always travels at crankshaft speed.

With a six-cylinder motor, the armature travels at one and one-half times the crankshaft speed, and as the distributer still travels at camshaft speed, the gear ratio between the armature and distributer is 3 to 1. Single-cylinder and two-cylinder magnetos have no distributer, the current being taken directly from the collector ring E. In a type of magneto recently developed for small four-cylinder cycle cars, there is no distributer in the ordinary sense of the word, the distribution being accomplished by two split collector rings.

The following table will give the armature speeds for dif-

ferent numbers of cylinders. It should be remembered that in all cases the distributer runs at camshaft speed, and that there are as many distributer sectors as there are cylinders:

(Four-Cycle Type Motors Only)

No. Cylinders	Distributer Gear Ratio	Armature Speed	Note
One	No. Dist.	Crankshaft Speed	....
Two	No. Dist.	Crankshaft Speed	....
Three	1½ to 1	¾ Crankshaft Speed	....
Four	2 to 1	Crankshaft Speed	....
*Five	No. Dist.	5/4 times Crankshaft Speed	Rotary Motor Dist. on Motor
Six	3 to 1	1½ times Crankshaft Speed	....
*Seven	No. Dist.	1¾ times Crankshaft Speed	Rotary Motor Dist. on Motor
Eight	4 to 1	2 times Crankshaft Speed	Single Magneto
Eight	2 to 1	Crankshaft Speed	Two Magnetos (each 4 cyls.)
*Nine	No. Dist.	9/4 times Crankshaft Speed	Rotary Motor Dist. on Motor
†Ten	5 to 1	2½ times Crankshaft Speed	Radial Aero Type
Twelve	6 to 1	3 times Crankshaft Speed	One Magneto for Twelve Cyls.
Twelve	3 to 1	1½ times Crankshaft Speed	Two Magnetos (each for 6 cyls.)

* Denotes the arrangement used with rotary engines in which no magneto distributer is used, the plugs of the rotating cylinders coming into contact with a stationary brush held by the magneto. The magneto is of the single-cylinder type.

† Denotes a radial arrangement of cylinders, all cylinders being stationary. Seldom used.

Typical Transformer Type Magneto.

The transformer type of magneto contains a circuit breaker and distributer as an integral part. It must be driven positively at a definite speed, the exact speed in relation to the

crank shaft being determined by the number of cylinders in the motor, or the cycle of the motor. A single primary winding Z of heavy insulated wire is placed on the armature, and the inner end is grounded at the point G-3, thus doing away with the necessity of a return wire. The breaker housing

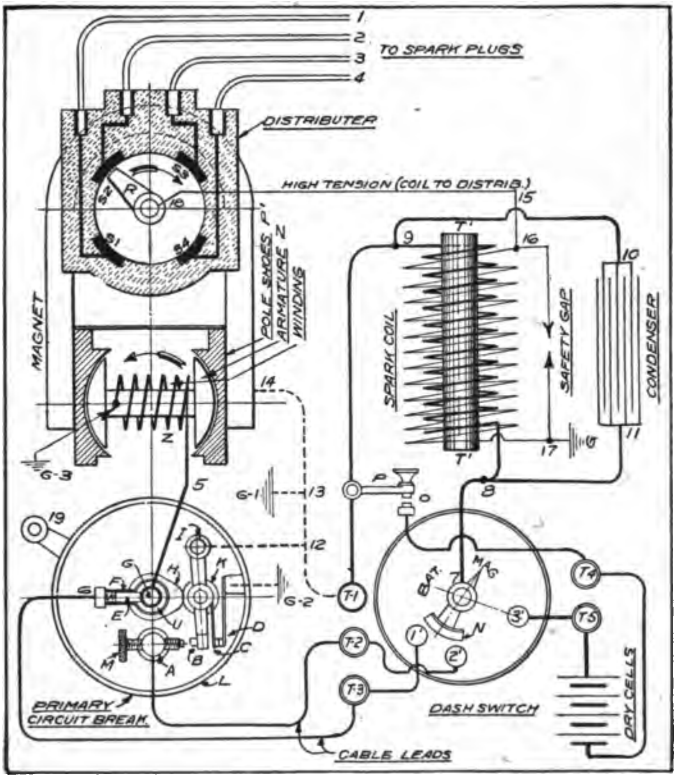


FIG. 2.—TYPICAL TRANSFORMER TYPE MAGNETO.

L in reality comes directly in front of the armature, but in the drawing it has been placed below so that the armature construction can be more readily seen. The pole shoes P of the magnet embrace the armature in the usual way. A lead

from the primary winding connects with a connector bolt G, which passes through the hollow shaft U, the bolt G being insulated from the shaft by the insulating tube. A copper brush E pressed on the end of G by a small spring in the rear, collects the current from the armature and delivers it to the circuit wire terminal 6, from which it flows to the coil terminal T-3. From the terminal T-3 the current passes to the switch contact 1,[1] across the switch blade N, where the current splits, part going through the coil and part flowing back to the circuit breaker through 2,[1] terminal T-2, and ends at the breaker contact A. A platinum-pointed contact screw M is adjustable in the insulated holder A. It should be noted that the brush E is insulated from the frame by the rubber bushing F.

A rocking breaker arm B swings on the pivot I, to which it is grounded to the frame of the magneto, this arm being swung back and forth by the cam H, which is mounted on the armature shaft U. The cam, rotating periodically, strikes the cam roller K fastened in the arm, opening and closing the contacts mounted in the ends of A and B at the point B. When these contacts are closed the armature circuit is grounded through I to 12, the dotted lines representing the grounded circuit. A pair of auxiliary contacts, C and D, mounted on the back of the rocker and on the timer housing, respectively, are for the purpose of breaking the battery current in the coil.

When the points separate, the current is broken in the primary circuit of the coil, causing a high tension spark. A small helical spring, not shown, pulls the arm B and the roller K, so that it is at all times in contact with the cam H. Since there are two maximum current impulses per revolution of the armature, the cam H is set so that the current is broken twice per revolution at the time when the armature is generating its greatest voltage The timer housing L may be rocked back and forth by the spark lever 19, by which the spark may be advanced or retarded. Rocking the housing causes the came H to come into contact, earlier or later,

with the roller, thus causing the spark to occur earlier or later in the revolution. The battery breaker C-D is grounded at G-2.

The spark coil, condenser, safety spark gap, the terminals T-1, T-2, T-3, T-4, T-5 and the dash switch are placed in a wooden box that is usually mounted on the dashboard of the automobile. The battery is connected with the box by T-4 and T-5, usually marked "Bat." on the instrument. The terminal T-1, marked "3" on the instrument, is grounded to the frame of the machine, while cables from T-2 and T-3, marked "2" and "A," respectively on the instrument, are connected with the stationary breaker contact and with the armature brush E.

Around the soft iron core $T\text{-}T^1$ are wound the primary and secondary windings as shown. In the case of this particular machine, the secondary winding consists of 3900 ohms of No. 34 wire, while the resistance of the primary is only 0.08 ohms, the ratio between the windings being nearly 40,000 to 1. The usual type of tin foil condenser is connected across the primary winding of the wires 9-10 and 8-11, this preventing sparking at the contact points A and B, and acting so as to increase the volume of the secondary spark.

A safety-spark gap is connected across the high tension terminals at 16 and 17, the distance between the discharge points being regulated so that the spark will jump across these points when the voltage becomes excessive at high speeds or in cases when the secondary leads become disconnected from the plugs. Limiting the voltage in this way does away with the danger of puncturing the insulation of the high tension windings. Usually this gap is about ⅜ inch wide, and at speeds above 800 revolutions per minute, or with more than 4 cells there is almost a continuous discharge when the plugs are disconnected.

A press button P is used for causing a spark at the plug when the engine is at rest, or for starting on "compression," as it is called. With a warm engine, having its cylinders full of mixture, it is very often possible to start the engine in

this way without cranking. The spark occurs when the contacts P and O are separated, the points P and O permitting battery current to flow for an instant through the primary of the coil.

The dash switch is mounted on the front of the coil box and has two switch positions, "Bat." and "Mag." When starting the switch indicator is thrown to "Bat.," and when the engine is firing regularly the switch is thrown to "Mag.," thus cutting the magneto in and the battery out of service. The normal running should always be done on the magneto.

In the sketch the switch is shown on the magneto position, in which the blade N shorts the contacts 1^1 and 2^1, bringing the armature current from 6 to the breaker contact A. At the same time the interrupted armature current is led from the switch 7 to the primary of the coil at 8, and from the other end of the coil at 9 to the ground at terminal T-1, and thence back to the armature, completing the circuit.

End 17 of the secondary coil is grounded at G, this connection usually being to the lead 9 T-1, as this saves one lead from the box to the frame. The other end of the high tension wire 16 leads through 15 to the axis 18 of the high tension distributer. From the coil box there are the following cables to connect:

2 wires from box to battery (low tension).
2 wires from box to magneto (low tension).
1 wire from box to ground (low and high tension).
1 wire from box to distributer (high tension).
4 wires from distributer to plugs.

The distributer board, shown in cross-hatch lines, is made of insulating material such as hard rubber or Bakelite. In this material are imbedded four metal sectors, S-1, S-2, S-3 and S-4 spaced at equal distances around the circle. It must be understood that there are as many sectors as cylinders, the present example being for a four-cylinder motor.

High tension current from the secondary of the coil is brought into the shaft of the rotating distributer arm R

through the wire 18-15-16. As the arm rotates it comes into contact with the sectors in order and thus connects the high tension current to the spark plugs 1-2-3-4 when contact is made with the segments S-1, S-2, S-3 and S-4, respectively. The distributer thus connects with the plugs in the proper firing order, while the circuit breaker determines the part of the revolution or the time at which the spark is to occur.

The distributer arm R is driven by a gear on the shaft 18 that meshes with a pinion on the armature shaft U, the gear ratio always being such that the distributer arm turns at cam-shaft speed. The gear ratio between the armature and the distributer varies, however, with the number of cylinders used.

The relation of the magneto speed to the speed of the motor or crank-shaft speed depends on the number of cylinders, a single, double and four-cylinder magneto running at exactly crank-shaft speed, while a three-cylinder runs at ¾ crank-shaft speed and a six-cylinder at 1½ crank-shaft. An eight-cylinder will run at twice crank-shaft speed. It must be understood that these speeds apply only to four-stroke cycle motors and to shuttle type armatures which give two sparks per revolution.

Two-stroke cycle motors demand twice the number of sparks per revolution, and for the same number of cylinders as each cylinder in this case fires twice as often. For the speeds of any other number of cylinders see the table under "Typical True High Tension Magnetos." This will also apply to the transformer type.

A type of transformer magneto that was designed by the author is shown by Fig. 3. In this magneto the transformer coil was enclosed in a metal case and placed in the opening between the magnets, thus making the magneto and coil one compact unit and avoiding the use of many wires and cables that are in evidence when the coil is mounted on the dashboard. In the diagram the coil, armature, condenser and circuit breaker are shown approximately in their correct relative positions.

A shuttle armature P is used, one end of the primary winding being grounded to the armature, while the other end is connected with insulated bolt D with the lead K. The heavy line indicates the insulation. A brush B held in an insulating brush-holder A presses on the enlarged head C of the connector bolt D, thus leading the armature current to the

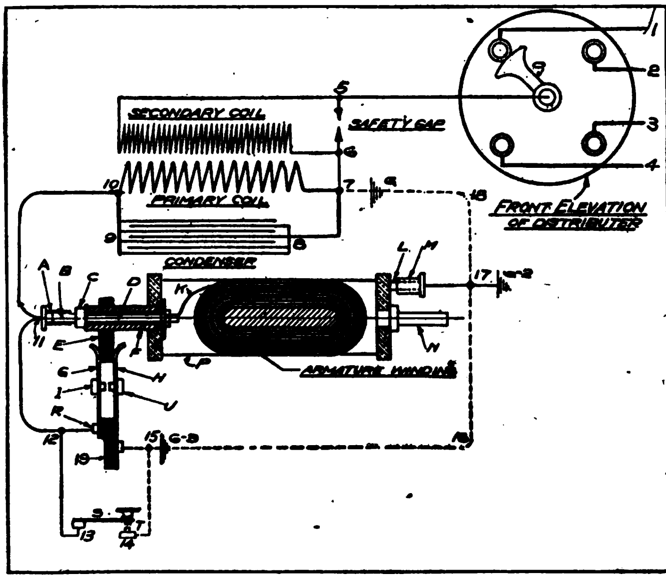


FIG. 3.—ANOTHER TYPE OF TRANSFORMER MAGNETO.

external circuit from 11. One lead 10-11 carries the armature current to the primary coil 10-7. Instead of depending on the armature ground connecting with the magneto frame through the shaft and bearings, a separate grounding brush L, held in the metal holder M, was used, this brush grounding the winding at G-2. This, as far as the diagram goes, was electrically the same as if the inner end of the winding was connected to the frame, but, mechanically, was much better, as it did not have to depend on a ground through the

varying conditions caused by grease or loose bearings. N is the shaft.

At 7 the end of the primary is grounded at G and is connected through the frame at 18, and to brush at 17, all dotted lines representing the grounded circuit. A tinfoil condenser 9-8 was connected across the coil as shown by 9-10 and 7-8. A safety gap 5-6 was connected across the secondary winding, the lead 5-0 going to the high tension distributer arm O. This arm, in rotating, made successive contact with the sectors leading to the spark plugs 1-2-3-4.

The other end of the armature circuit lead from the brush Bat. 11 to the interrupter at R through wire 12. This interrupter consisted of two metal blades G and H, spring tempered, mounted and insulated from each other on the block 19. Two platinum contact points I and J made normal contact with one another, grounding the armature current through 15 at G-3, and from here along the frame 15-16 and 16-17 back to the other end of the armature winding.

SINGLE—DUAL—DUPLEX—TWO-POINT SYSTEMS.

Magneto Wiring and Connections.

When used as an independent source of ignition, the wiring of a magneto is a very simple proposition, but when used in connection with a battery auxiliary, the amateur electrician often becomes confused with the multiplicity of wires and connections. The additional circuits due to a self-starting and lighting system by no means tend to simplify matters.

In general, the circuit of an independent magneto depends upon the type of magneto, i. e., whether it is of the true high tension type or whether used in connection with an external spark coil, since in the latter type there are several primary wires leading from the magneto to the coil on the dash. When this system is "double," that is when two plugs are used per cylinder, the high tension circuit is different than with the single system. To simplify matters, we will confine our at-

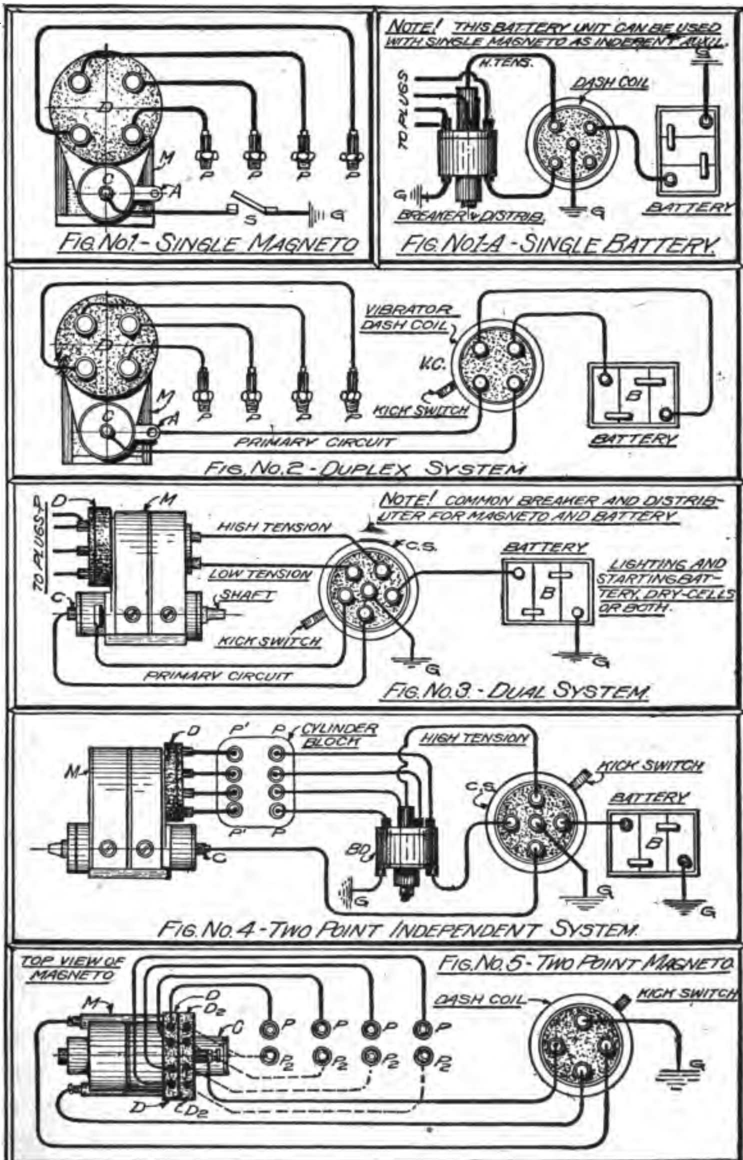
tention at present to the combinations commonly used with the true high tension type, or the type in which the magneto windings generate the high tension current without the use of external coils.

Independent Magneto—When a magneto is used without batteries, as in diagram No. 1, there is a high tension lead from each plug P in the cylinders to a corresponding connection post on the distributer D. A primary or low tension wire leads from the circuit breaker C to the switch S located on the dash. The remaining terminal of this switch is "grounded" or connected to the frame of the car or engine. With some late types of magnetos there is no switch S, this short circuiting switch being embodied in the circuit breaker casing, so that the magneto is cut out by moving the spark lever on the wheel to "full retard." When installing the magneto care should be taken to have the magneto base in full metallic contact with the frame of the motor, so that the magneto will also be effectively grounded for the return of the current. The advance and retard of the circuit breaker is shown by A.

Dual System—In the dual system both a battery and magneto are used, the former being used in starting and as an auxiliary against the failure of the magneto. With the dual system a single set of plugs is used for both the magneto and battery, and the magneto distributer distributes the high tension current for both. The usual connections are shown by Fig. 3, in which CS is the battery spark coil and switch mounted on the dashboard, B is the battery, M is the magneto with the circuit breaker C and the distributer D. And as in the first case, P are the plugs in the cylinders.

As will be seen from the diagram, one pole of the battery is grounded to the frame, as is also one terminal of the coil.

Duplex System—In the duplex system both the magneto and battery are used, and in some cases an independent vibrator is introduced into the starting system. Instead of having



FIGS. 1-1A-2-3-4-5.—SHOWING DIFFERENT HIGH TENSION MAGNETO WIRING SYSTEMS.

a separate coil for the battery, as in the dual system, the primary and secondary coils on the magneto armature are used to produce the spark when the battery is used In this type, the circuit breaker and distributer of the magneto are used in common by the battery and magneto. In starting, the switch is thrown so that the battery current passes through the primary winding of the magneto armature, the interrupting and timing being performed by the circuit breaker, each interruption causing a spark at the plugs. The high tension current from the secondary winding of the armature is led to the distributer as in the case when the magneto is working alone.

When running normally on the magneto alone, the battery is cut out of circuit. To increase the spark at starting, the Bosch duplex magneto has a vibrator in series with the armature (see Fig. 2), which is cut out in normal running. In Fig. 2, VC is the combined vibrator and dash switch.

Two-Plug Independent System—To insure complete independence of the battery and magneto systems, the circuits are made entirely separate from one another, as shown by Fig. 4, there being two separate sets of plugs P and P,[1] the first for the battery spark and the second for the magneto. Unlike the previous systems, there is a distributer BD and circuit breaker for the battery system, and a circuit breaker C and distributer D for the magneto M. The battery coil CS carries a switch which opens and closes either independent circuit. The battery B is grounded on one side.

This arrangement makes the secondary wiring very complicated and difficult to arrange properly on the motor, since there are twice as many high tension leads to take care of. Since the plugs are the most common source of trouble, the complication due to wiring and the installation of a separate distributer do not make this system advisable in ordinary cases. The comparatively unused battery plugs are generally foul when called upon in an emergency, and therefore the system is little more, if any, reliable than the dual system

unless one wishes to assume the trouble of caring for twice the necessary number of plugs.

Two-Point System—To increase the output of a motor, especially on racing cars, it has been common practice to have two sparks occur simultaneously in the same cylinder at rather widely separated points in the combustion chamber. Whether this amounts to any material increase is rather doubtful. A recent test run showed that the increase was only in the nature of 5 per cent, an amount that in an ordinary pleasure car would hardly justify the additional complication and expenses.

By installing two points of ignition it was thought that the distance through which the flame had to travel would be reduced, since there were two points from which the flame would spread. An increase in the rate of combustion obtained in this way would naturally decrease the loss of heat to the jacket water, and therefore increase the power. This effect, of course, would be more pronounced in the case of a T-head motor where the distance across the combustion chamber is at a maximum. In the case of the T-head in a certain test this increase amounted to 10 per cent under conditions very favorable to the system, that is, the cylinders were very large, deeply pocketed, and the piston velocity was extremely high. With the automobile in ordinary service the advantages are questionable, especially with L-head or motors having overhead valves.

In general there are two ways of producing the double spark from a single magneto. (1) By providing the magneto with a double distributer, one distributer for each set of plugs and arranged so that each distributer causes simultaneous sparks in each cylinder. (2) By means of a single distributer and special plugs, one plug in each cylinder being of the double pole variety in which both sparking points are insulated from one another and from the metal of the cylinder.

The first method is shown by Fig. 5, in which the double distributers D and D^2 control the two sets of spark plugs P and $P,^2$ respectively. The plugs used in this system are of

the ordinary type. The primary connections are practically the same as those of the single magneto, and the system can also be used in dual with the battery.

With a single distributer, the high tension circuit must be arranged so that the current passes through the first plug, across the points to the second plug and thence to ground or to the cylinder of the motor. This necessitates, of course, insulating both of the points of the first plug from the cylinder, for if either of the points make contact with the metal, no current will flow to the second plug. The second plug is of the ordinary variety.

Electric Starting and Lighting.

General—When using electricity as a medium for "cranking" the gasoline motor it is possible to use the current also for ignition and lighting as well as for the electric horn and gear shift. The possibility of operating so many auxiliaries from the same source of power naturally makes the electric self-starting system by far the most popular. In many cases an independent magneto is used and sometimes in addition a third auxiliary, the dry cell system, is added to the ignition system making the car entirely independent of any one system for the ignition current.

Disregarding the ignition system for the time being, the self-starting and lighting system is composed of the following principal units:

(1) The generator for supplying the current for the cranking of the car and the lighting system.

(2) The motor for spinning the motor. (Sometimes the generator and motor functions are supplied by a single unit.)

(3) Storage battery for storing current for the motor and lights as well as for the horn and ignition.

There are four ways in which a single unit may act as both generator and motor. (1) A single armature, field and commutator may give or receive current to or from the storage battery. (2) A unit with a single field and armature may be

provided with two commutators and two independent windings on the armature, one winding being for the generator while the remaining winding and commutator is for motor service. (3) Two independent armatures, fields and commutators may be contained in the same frame, the armatures being mounted on the same shaft in tandem, they being electrically independent of one another during the starting and generating periods. (4) Instead of being in tandem the fields and armatures may be mounted in the same casing but one above the other. (Double deck.)

When types (1) and (2) are acting as generators they are generally driven by the engine through the timing gears. When operating as motors they drive the engine either through a gear toothed fly-wheel or by a silent chain to the crank-shaft. The driving pinion is so arranged that it can be thrown in and out of mesh with the geared fly-wheel by the starting pedal, the gear being normally out of mesh when the engine is running under its own power.

Regulation of Generator Current—The faster the armature of a generator rotates, the higher will be the voltage, and the greater will be the current put through the storage battery. With a continually fluctuating speed due to the variations of the engine it is evident that some device must be provided that will limit the current sent through the storage cells and at the same time prevent the storage battery current from surging back through the generator when the generator falls below the voltage of the battery.

In general there are four ways of limiting the current. (1) By providing the generator with a governor so that it cannot exceed a certain speed. (2) By placing an automatically controlled resistance in the generator circuit that will keep the current steady at any ordinary speed of the generator. (3) By providing an automatic cut-out switch that will open the circuit when the current exceeds or falls below certain points. (4) By inherent regulation of a specially wound generator in which the windings oppose one another and diminish the output as the speed increases.

Double Unit System—There are several systems in which the generator and motor are entirely independent of one another and are mounted in different parts of the chassis. The motor is series wound while the generator is compound wound, the difference in winding being due to the fact that a series winding gives greater "torque" or pull while the compound winding tends to maintain a constant current.

The Cut Out—A cut out is an automatic switch which opens the generator circuit when the voltage of the generator falls below that of the battery so that the current from the battery will not be discharged back through the generator. This generally consists of an iron core on which a double winding is placed. One winding which is connected across the terminals of the generator consists of many turns of fine wire, while the other coil consists of a few turns of heavy wire connected in series with the circuit leading to the storage battery.

When the generator comes up to voltage, the fine wire coil magnetizes the bar so that the armature is drawn up causing the current to flow into the battery through the switch. The main current now flows through the heavy coil reinforcing the magnetic effect of the first coil.

Should the generator now fall in speed so that its voltage is less than that of the battery, the current will be reversed in direction through the second coil which will therefore oppose the first coil, demagnetize the iron core and allow the switch to be opened by the tension of a spring connected to the armature.

Generating Speeds—All other conditions being constant, the speed of a dynamo or generator determines the voltage, the voltage increasing in almost direct proportion to the speed until the "saturation" point of the generator is reached. To obtain the desired voltage it is therefore necessary to have the generator run at a particular relation to the normal running speed of the motor. Gearing the generator at a high ratio allows the current to be developed at low engine speeds

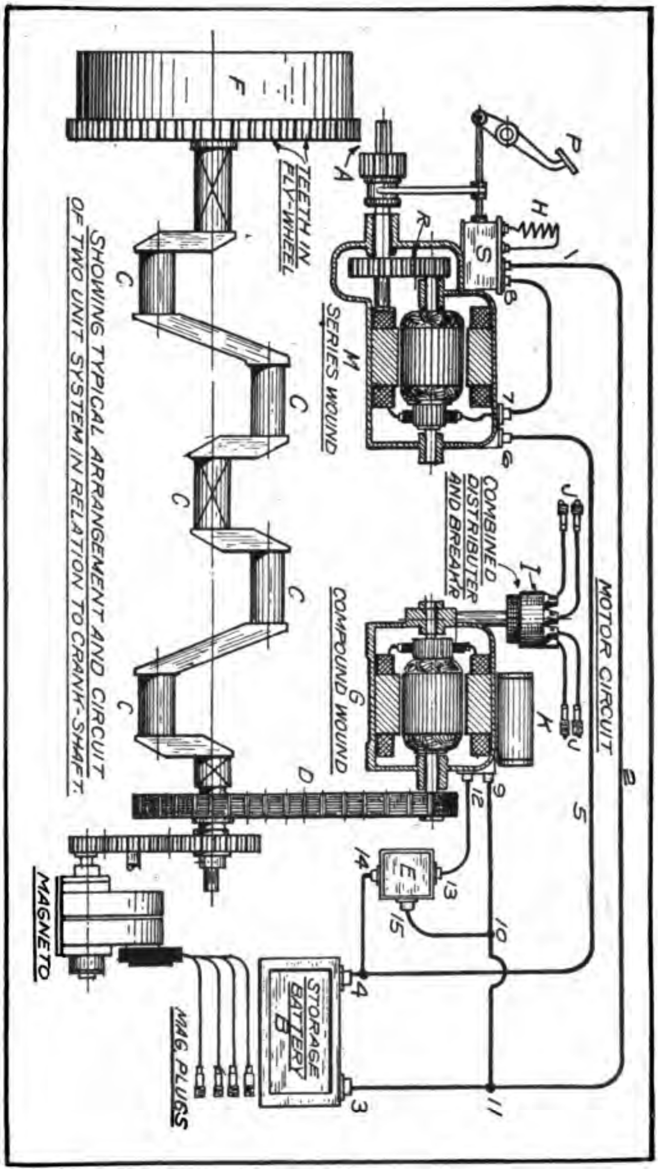


FIG. 1.—DOUBLE UNIT SYSTEM FOR STARTING AND LIGHTING.

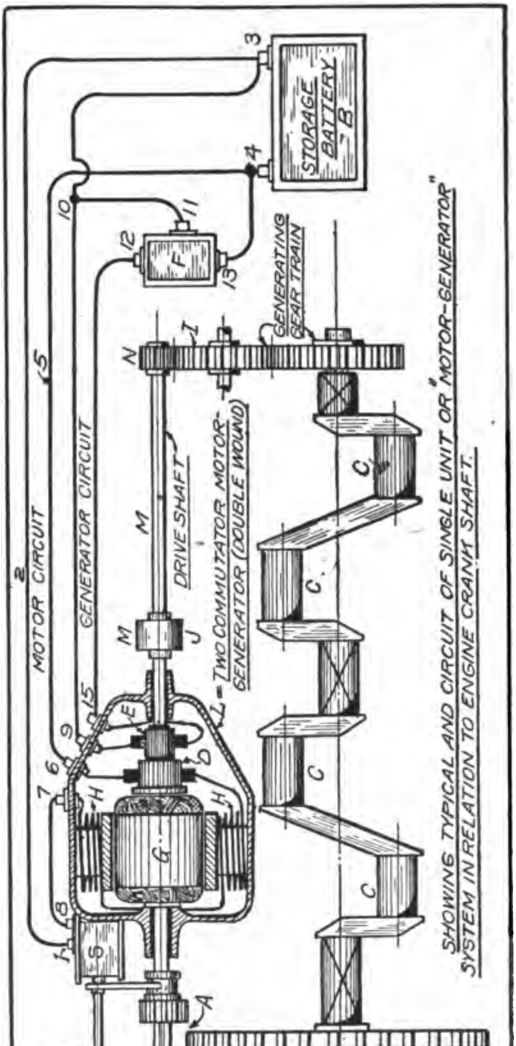


FIG. 2.—SINGLE UNIT SYSTEM FOR STARTING AND LIGHTING.

Connecting Motor and Generator to Engine.

Connection between the generator and the motor to the engine depends to a great extent upon the arrangement of the engine and the other accessories, the three principal arrangements being as follows:

(1) Geared connection to fly-wheel (already described).

(2) Chain drive to crank shaft, or,

(3) Through the magneto or pump shafts, and thence through the timing gears to the crank-shaft.

In addition to the above is the U. S. L. system in which the motor-generator is mounted directly on the crank-shaft in place of the usual fly-wheel. This is the simplest type of all since it dispenses with the usual gears, bearings, clutches and shafts of the other systems, and reduces the weight of the machine by an amount approximately equal to the weight of the fly-wheel.

When the drive is through the fly-wheel, with independent motor (M) and generator (G) as shown in Fig. 1, the motor end is cut in and out of service by throwing a pinion (A) in or out of mesh with the teeth cut in the circumference of the fly-wheel (F) by means of the starting foot pedal (P).

A switch (S) is opened or closed by the same movement of the pedal, which opens or closes the circuit between the storage battery (B) and the motor. Depressing the pedal throws the pinion in mesh with the fly-wheel and closes the switch allowing the battery current to flow through the motor, thus turning the crank-shaft over and starting the motor. The second set of reduction gears is shown at (R). A resistance coil (H) is generally put in series by the switch which allows the motor to turn over very slowly until the gears are in mesh. When the pinion is forced clear across the face, the further movement of the switch short-circuits the resistance, allowing the full current to flow and the motor to build up its full speed.

The independent generator (G) is shown in driving relation to the crank-shaft (C), the drive being through the silent chain (D). The generator in this system is always con-

nected to the crank-shaft no matter whether the engine is starting or running normally. A cut-out (E) is shown in series with the generator circuit (the purpose of the cut-out was described in an early part of this chapter). The distributer (I) is shown on generator feeding the spark plugs (J), the coil being at (K).

In Fig. 2 is shown the motor-generator arrangement in which the functions of motoring and generating are performed by a single unit (L). When starting, the pedal (P) meshes the pinion (A) with the fly-wheel gear teeth (K) as before described, the switch (S) performing the same way as in the two unit system. An extension of the armature shaft is driven through the gear train (I) when the unit is running as a generator.

Since two speeds are required for motoring and generating it is evident that some form of slip clutch must be provided as at (M) so that the armature (G) will be disconnected from the gears (I) when the motor is starting the engine and is running at a high speed. This clutch is usually of the ratchet type which will allow the armature shaft to run faster than or to run past the gear (N).

It will also be seen that with this type there are two independent commutators (D) and (E) for the two windings on the armature (G). A single pair of poles (H)-(H) serve for both the motor and generator windings.

Voltage and Battery Arrangement—In general there are three voltage arrangements at the present time, a straight system where lights, motor and battery operate at six volts; a straight twelve volt system; and a mixed system in which a double six volt battery supply current at twelve volts to the motor and at six volts for the lamps, horn and ignition system.

With the mixed system, the twelve volt leads are connected from the end terminals of the battery, while the six volt circuit is obtained by a third wire connected to the middle cell. A connection made between this third wire and any of the others gives six volts.

CHAPTER X.

DIFFERENTIAL GEAR.

Gear, Differential—A differential gear, sometimes called a "balance gear," is a simple device which is misunderstood by the average car user, partly because it is never very accessible, and partly because it is very difficult to describe on paper. A British writer says: "In 1827, some of the motor 'buses which profitably plied for hire about Cheltenham and in London, had each of their wheels fastened by a pin to a solid rod of iron which constituted the live back axle. In several of these 'buses the axle was driven by a chain, but none of them had a differential. It is instructive to learn what happened.

"When they wanted to turn a sharp corner, say to the right, it was noticed that the inner or right-hand wheel had to traverse a much shorter circular path than the outer or left-hand wheel, and consequently had to make less revolutions than the left wheel. But the axle, which was coupled rigidly to both wheels, opposed itself to this difference in the amount of rotation, and rendered it mechanically impossible for the two wheels to turn at different speeds. It therefore became the custom to stop the car at a sharp corner and pull out the pin which fixed one of the wheels to the axle (preferably the inner one on the curve). (See Blue Book of Committee Report on Steam Carriage on Roads, 1831.) On removal of the pin this wheel was then no longer a driving wheel and the axle could freely rotate inside its hub, while the outer wheel was driven by the engine as before, and traversed its longer circular path without difficulty.

"Provision was doubtless made to prevent the loose wheel from slipping off completely during this manoeuver. When the corner had been turned, the pin would, in the ordinary course, be reinstated, but it is in human nature to suppose that

the post-boy, to whom this particularly greasy job was intrusted, disliked it and shirked it, and was rewarded by finding that his motor 'bus proceeded along its journey just as well without the pin as with it.

"There was a drawback, however. The power of the engine under these circumstances was entirely transmitted by one road wheel, and on coming to hills this wheel would skid. The evidence before the Committee shows that these early motorists made a practice of stopping near the foot of steep hills to rake their fires and get up steam, thus affording an opportunity for replacing the pin.

"It is probable that turning to the right was easier than turning to the left when the right-hand pin was removed, but in neither case was the turning so hard as when one wheel had to be bodily scraped across the ground."

This plan of freeing one wheel foreshadowed the plan (employed a few years ago on very small cars and now being resuscitated) of employing a "free wheel clutch" on each of the back wheels of a car instead of a differential.

All this impresses the fact that every curve traced by a car requires the wheel on the outer side of that curve to rotate faster than it did when the car was going straight. The wheel on the inside of the curve obviously has to go slower so that in a conceivable case (on a very sharp curve) the inner wheel might have to be almost stationary (acting as a pivot) while the outside one would run round it in a circular path.

Nowadays, we recognize this fact, and to free the wheels from one another we cut the axle in two so that one half axle corresponds to one wheel and the other half to the other wheel. As both wheels must be driven, we mount a bevel wheel (A′ and B′ of Fig. 1) on each half axle, and allow a small portion of the axles to project so as to form a center for a very simple device (Fig. 2), which is placed between them. We drive that device round by means of a flat belt or a chain or propeller shaft, or indeed by any mechanical means, and the thing is done. We have chosen a flat leather belt in the

figure simply for convenience. (The propeller shaft arrangement will be shown later.)

This pulley has a hub or center which allows it to spin freely on the projecting pieces A and B of the cut axle of Fig. 1. From the hub three or four round spokes are used to support the belt pulley's rim.

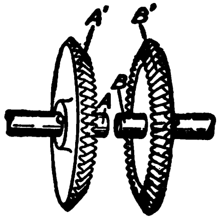


Fig. I.—A Bevel Wheel fitted to each half axle.

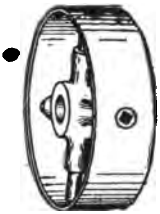


Fig. II.—Belt Pulley, arranged to run freely between the two bevel wheels A1 and B1 in Fig. I.

If it be put in position and driven by a belt from the engine it will not drag the two half shafts round with it unless at least one of its spokes is fitted with a small conical pinion C. To show this clearly Fig. 3 is drawn, which is Fig. 2 turned round a little more so as to disclose the bevel wheel. We shall not

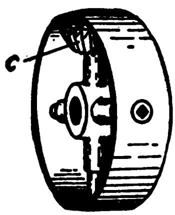


Fig. III.—Same Belt Pulley fitted with a conical pinion on one spoke.

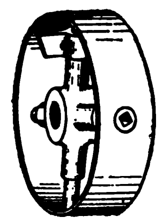


Fig. IV.—Same Belt Pulley fitted with pivot bar instead of pinion.

have to introduce another bevel wheel or pinion or mechanism or complication of any sort. We have, in fact, a complete differential or "balance gear" in this very simple system, and every other kind of differential in daily use, no matter how complicated in appearance, is the same as this and can be understood by having understood this.

When the belt pulley is turned round, it is clear that either (1) both half axles must turn, or (2) half axle A must turn, or (3) half axle B must go round.

If there is no friction, that is, if no one grasps either of the half axles in Fig. 1, both will rotate at the same speed as the belt pulley, so that the central pinion might just as well be replaced by a small pivoted iron bar as in Fig. 4. The ends of the iron bar are cut on the slope, so that they should fit between the teeth of the bevel wheels A and B, Fig. 1, and to prevent the bar from falling out, it is pivoted loosely on to one of the round pulley spokes, as shown.

The two arms of this iron bar are like the two equal arms of a balance. If there be equal pressure or equal resistance to motion on the two arms of a balance, whether this resistance be large or small, the balance arm does not turn. If there be an excess of resistance on one side, the bar turns or yields on that side. If we call the movement of the balance arm, on which there is the excess pressure, a backward movement, the arm on the other side moves forward by an equal amount, until, if the excess pressure continues, the balance arm slips out from between the teeth of the two-side bevels. This gives us the reason why a little pinion, as in Fig. 3, is used instead of a bar. Its action is exactly the same as the bar, but it has this advantage over the pivoted bar on the balance arm, that when a large "out-of-balance pressure" is exerted and maintained, another pair of teeth come into engagement with the teeth of bevel wheels A and B.

Let us now consider the whole appliance in action. When the car is traveling forward, driven by the belt pulley, the pressures on the two arms of the bar are equal to one another. When, however, the steering wheels are deflected to one side, it is clear without any mathematical demonstration that the car no longer rolls forward as easily as if all the wheels were pointing in the same direction as that in which the car is traveling. The steering wheels therefore introduce a resistance to forward motion, which may be slight or may be great, according to the amount of deviation from a straight course,

and this resistance is not the same on the two sides of the car. There is, in fact, a greater resistance to forward movement from that steering wheel which is on the inner side of the curve. On a motor car the steering gear is so contrived that whichever front wheel is the inner wheel (and therefore runs round the smaller radius of a curve) is always more deflected than the outer wheel. To a person who has never owned a motor car the same fact can easily be brought home by a simple experiment with any wagon or four-wheeled carriage. Turn the front wheels of the wagon round through a sharp angle, and then attempt to push the wagon by hand from the back wheels. First try pushing at a spoke of the inner back wheel, and then try pushing a spoke of the outer back wheel. It will be found that when the outer back wheel is being pushed the wagon is moved very much more easily.

In other words, an excess of resistance is offered by the inner back wheel, that is, the wheel which is on the inner side towards which the steering is deflected. If the belt pulley of Fig. 3 or Fig. 4 is driven round by the engine, exerting continually a certain effort, that effort is always, and under all circumstances, divided into exactly two equal parts by the balancing effect of the pinion (or the lever arm of Fig. 4), but whichever half axle offers the less resistance obviously turns more easily precisely in proportion as the resistance is less. So the differential gear performs its function, and drives the outer-driven wheel to turn more than the inner wheel, and this difference is the greater the sharper the curve.

A Second Explanation.

As one man's difficulty in understanding a mechanism is not the same as another's, so it may be useful to some readers to have a totally fresh and independent explanation from a different standpoint. Here are, therefore, two illustrations, and some very lucid text which originally appeared in The Horseless Age.

In Fig. 5 A and B are two racks—that is, straight, rectangular bars with teeth cut on them. These racks are rest-

ing on the floor and free to move vertically in guides. They are loaded down by weights W, W^1. Between the racks is interposed a pinion, which rotates round E, supported in the yoke D. If a lifting force be applied to the yoke D, in the direction of the arrow, and the weights W, W^1 be equal, as well as the weights of the two racks, and their friction in the guides, then the two racks will be lifted together and the pinion will not turn, but will remain in the same relative position to the racks.

If we add to the weight W^1 another, W^2, and again apply a lifting force to the yoke, then the resistance to motion of rack

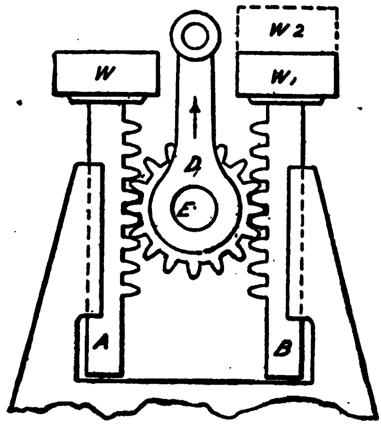


Fig. V.—Model to explain differential gear.

B being greater than the resistance of rack A, B will remain stationary. A will rise and the pinion will turn about its shaft E. This is under the supposition that the additional weight W^2 more than counterbalances the friction of the pinion at its shaft and at the teeth. We have then a differential motion, the same as in a differential gear, which is brought about by increasing the resistance to motion of one of the racks.

In a differential gear of the bevel gear type the two racks in the illustration (Fig. 5) are represented by the two side bevel gears (Fig. 6) and the pinion C is a bevel pinion, of which three or more are usually provided. The power is again

applied at the shaft of the pinion, to which in the figure a handle is shown attached, but which in practice is connected with a sprocket or chain wheel. As long as the resistance to motion of the two bevel wheels A and B is equal, the pinion C will not turn on its center D, but will simply rotate round the center of the shafts F and G, which are the two halves of the driving axle, and will carry the bevel wheels A and B along with it, the two (A and B) thus rotating at the same speed.

Now, suppose that the resistance to rotation of B becomes greater. This occurs when the steering wheels are turned to that side. Then pinion C will begin to revolve round its

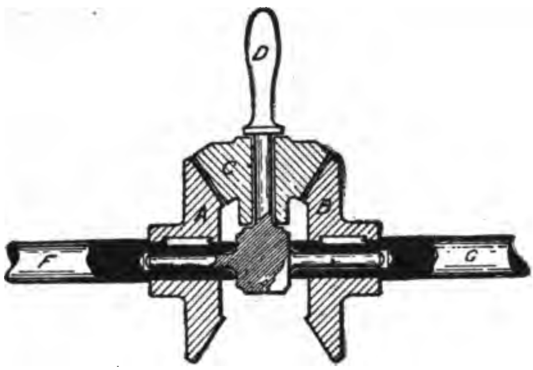


Fig. VI.—Model of Bevel Differential.

shaft and allow bevel wheel A to turn faster than bevel wheel B. These two bevel wheels are connected through the two half-axles to the driving wheels, and hence, if these bevel wheels turn at different speeds, the driving or road wheels do also.

In the crypto type of differential many makers utilize flat gear wheels instead of bevel wheels, because they can be more accurately cut, and from that point of view this form of differential is an advantage. Purchasers are prone to pay insufficient heed to the differential being of good make and free running. It is probable that if they realized what a difference a good differential may make to the life of the driving wheel tires, they would alter their attitude in this respect.

Although we have now described everything in a differential, we must not forget that in ordinary parlance the term is erroneously used to include a great deal more, namely, everything contained in the differential case.

If, in place of the belt drive employed in the example (Fig. 3), another mechanical drive, namely, a bevel drive, were used, the addition of the external bevel wheel and its pinion would lend to the gear the appearance of Fig. 4. But we must not be led to suppose that this driving gear is essentially part of the differential. It has nothing to do with it. It is merely placed in a case in close proximity to the differential. Lastly, it may be said that instead of one pinion C being

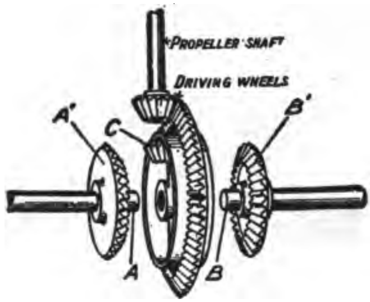


Fig. VII.—Complete Differential showing bevel, drive and pulley.

placed on only one spoke, it is usual to place two or three such pinions all performing exactly the same function on the other spokes, and further, if the drive shown in Fig. 7 is adopted, the side thrust due to this form of drive must be taken by thrust bearings, which are usually ball bearings. All these extra details are shown in the completed figure of an actual differential gear (Fig. 8).

Further Effects of the Differential—If the car be jacked up so that both driven wheels are clear of the ground and if the engine be run so as to drive the wheels round, they will turn at the same speed if they are equally free from friction and if the brake bands are clear. If now one wheel be stopped by hand, the other will be found to rotate at double the previous speed.

If the engine be stopped and the brake be applied to the propeller shaft so as to lock it, it will be found that if one of the driving wheels be turned forward by hand, the other wheel will rotate backward by a precisely equal amount, and at the same speed.

The knowledge of both these facts is important to the driver of a car because of its bearing upon the best way to avoid skidding, side-slipping, and indirectly the excessive wear of tires.

In the course of ordinary straightforward running the differential is always slightly in action, because the adhesion of the two driving wheels is never exactly the same. That is (1) owing to the uneven distribution of the weight of the passengers, or because the car itself never weighs exactly the

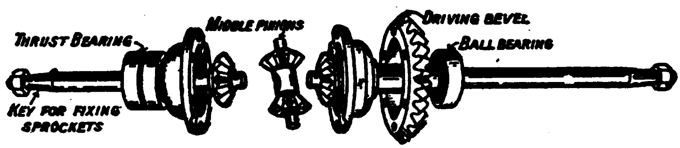


Fig. VIII.—Complete Differential as used on car.

same amount on both driving wheels; (2) owing to the surface of the road being invariably different to the two wheels to a slight degree. Thus either a road depression is under one wheel or an excrescence is under one wheel or a more slippery surface is under one wheel.

Now, no matter what difference of adhesion there may be between the two wheels and the ground, the differential provides that no more effort can be exerted on the wheel which has the more adhesion than on the wheel which has the least. Thus the forward effort on the car can never be more than that due to twice the smaller adhesion, and further as the efforts from the two wheels are always equal, the forward effort on the car is always applied to the car, as it were, from the center of the back (or driving) axle. If the wheels were keyed solidly to a solid axle without differential, the wheel which had the best adhesion with the ground would obviously transmit the larger part of the forward push, so that the result-

ant push or effort from both wheels would not be at the center of the back axle, but nearer to one side, the side of better adhesion.

This then is an advantage of the differential when the car is in use on the road in many cases, but in some of the situations which arise in the course of traveling by road, this very merit presents certain complementary disadvantages. Thus if, as often happens, one driving wheel has good adhesion, while the other is on very slippery ground, it is evident that the differential prevents the wheel which has good adhesion from driving the car forward with any better effect than if both wheels were on the same slippery piece.

The good adhesion of the wheel which is on good ground is, of course, capable of preventing side-slip of the car, but it is not capable of being utilized for forward propulsion beyond the amount which is possible to the other wheel on slippery ground.

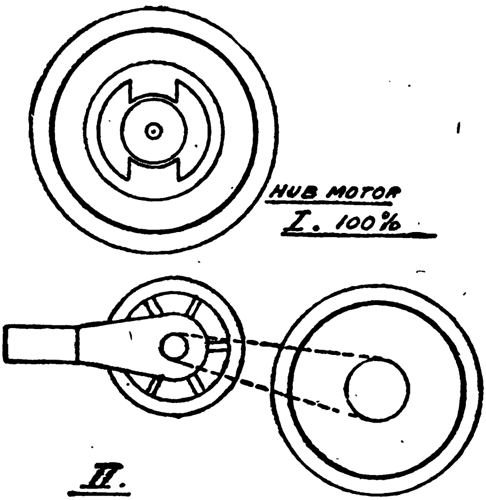
In other words, a car which had a solid axle without differential should travel forward more quickly on a surface of which some parts were more slippery than others, because it would invariably be able to utilize to the full for forward effort whichever wheel presented the best adhesion, plus the small, but still not negligible effort on the other wheel. This advantage, and a certain superiority in avoiding side-slip, would also accrue to a car fitted with two "free wheels."

GEAR EFFICIENCY.

Users of cars cannot fail to be interested in the following figures of efficiency for various kinds of gear road wheels and tires. They are reported by a European authority from electrical experiments by Mr. R. Lacau.

"As an instrument of research electricity is invaluable in this as in every other industrial field, because it allows of the use of accurate measuring and recording instruments, which

eliminate personal error and enable a whole laboratory to be transported readily to the scene of the test, even on a motor car. One of the most striking results thus measured is perhaps the high efficiency established for a well greased roller chain in spite of its exposure to air and dust. Ninety-four per cent of the energy put into a roller chain in actual use on a car re-appeared as energy on the back sprocket, and whereas a pair of steel spur wheels similarly exposed only returned 90 per cent. These were the figures for new apparatus. When

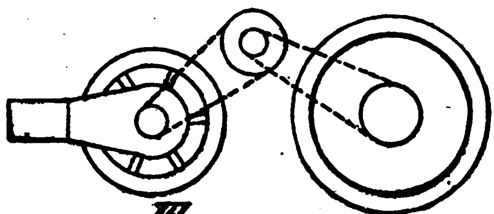


I. The most efficient drive. No gear reduction. Electric motor on the axle.
II. The second most efficient drive. One chain reduction. The motor and road wheels rotating in the same plane, 94 per cent. when new, 92 per cent. when worn.

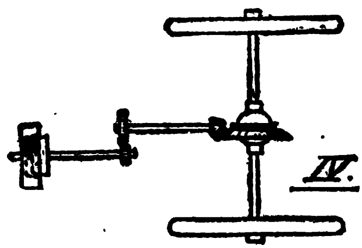
the chains were worn, the number fell to 92 per cent, but when the spur wheels were worn the number fell to 80 per cent, and this is where the important difference comes in from the point of view of the power. Spur wheels, it will be urged, are not generally run exposed to the dust and air, but in gear-boxes full of oil. Under this condition 92 per cent of the energy put into the first wheel was obtained from the second when all was new, and only 90 per cent when worn, so that even the new spur wheels cased in were only about

equal in efficiency to the worn roller chain exposed to the dust and air.

"It is not always, however, that a plain spur wheel is to be contrasted with a chain. It is sometimes the much less efficient apparatus, a bevel spur wheel, that must be compared, and such wheels well cased, running in oil and brand new, afforded 88 per cent, or when old 82 per cent efficiency only. The bevel wheel arrangement is in the case of many types of car associated inevitably with the Hooke coupling or universal



III.



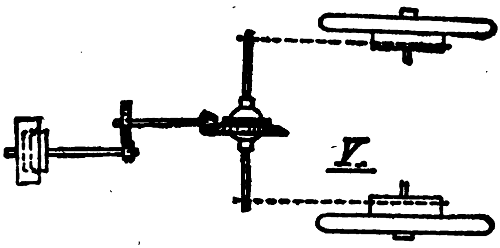
IV.

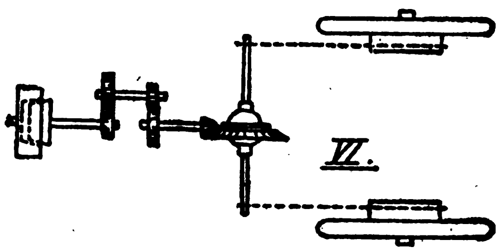
III. Two reductions of speed by chain, 88 per cent. when new, 84 per cent, when worn.
IV. " " " but power taken round a right angle, 79 per cent. when new, 65 per cent. when worn.

joint. It is not always appreciated that this ingenious device wastes power. It does not waste much, but even when new it does waste some, and if 100 H.P. is put in at one end of the shaft only 96 per cent can be got out at the other under ordinary road conditions. It will be understood in this, which appears like a tirade against bevel driven live axle cars, that nothing of the sort is intended. Such cars may, if well constructed, be far superior to certain, or even all existing chain-driven cars, but for the sake of the present investigation attention must be directed to one point at a time, and that one

point for the moment being efficiency of transmission, there is no question but that the chain is shown by experiment to be superior.

"In view of the great demand for very silent drives, even for auxiliary plant, such as pumps, magnets, etc., the steel pinion and fiber ring, and the rawhide pinion with cast iron rings have an interest, inasmuch as it is perfectly legitimate for an intending purchaser to ask himself whether he would





V. Three reductions of speed, one being right-angled drive, 74 per cent. when new, 60 per cent. when worn.
VI. Four reductions of speed, one being right-angled drive, 67 per cent. when new, 49 per cent. when worn.

prefer to consume a little more fuel and travel more quietly, and if that be all that enters into the problem he would probably consider it wise to prefer the quietude and pay the price. The efficiencies of these two silent combinations appear to be in both cases 88 per cent with new gear and about 80 per cent with worn.

"It must not, however, be assumed that because it is easier to make the fiber and rawhide combinations more silent than the plain steel ones, that in certain conditions it is not pos-

sible to approach to the same degree of quietude at a little more expense in the accurate gear cutting of steel wheels.

"Road Wheels—Many owners have believed the tractive resistance of solid tires to be less than that of pneumatics under certain conditions. Not having been able to bring anything but roughly approximate experiments to support the view they were glad to have Mr. Lacau's confirmation by experiment of a careful kind to show that on the electrical car on which the tests were taken at 13 miles an hour on good dry macadam, free from dust, the tractive pull per ton was 33 lbs. to 40 lbs. with solids; 44 lbs. to 53 lbs. with 90 mm. pneumatics; 53 lbs. to 62 lbs. with the same pneumatics partly inflated; and 64 lbs. to 71 lbs. with 120 millimeter pneumatics on the same car."

CHAPTER XI.

SPUR OR TOOTHED GEAR.

Gear, Spur—Gearing composed of spur wheels, the latter being the ordinary form of cogwheels. The cogs are radial and peripheral, and are adapted to engage countershaft cogs on another wheel. The pitch-lines of the driving and the driven wheels are in one plane. See Gear or Gearing.

Spur wheels or toothed gear wheels are liable to damage from the following causes:

(1) From being overloaded, or asked to transmit an effort greater than the engaging teeth are jointly strong enough to bear, for example, when a countershaft brake is used too violently.

(2) From being mounted on engaging wheels whose axles are badly aligned or at the wrong distance apart.

(3) From being badly cut, or cut to a bad profile.

(4) From being badly handled by the driver in one of four ways:

(a) Allowed to drive when only in partial engagement.

(b) Allowed to take up the drive with a blow or shock, instead of taking up the pressure gently.

(c) Brutally forced into engagement.

(d) Being neglected as to lubrication.

All these cases are really methods of obtaining an overload on the teeth.

Alignment—Thus in (2) the effect of bad alignment is that the whole pressure due to the transmitting the effort of the engine comes upon an edge of the teeth instead of acting upon the whole width, thus overloading the acting edge. Bad alignment after an overhaul in an amateurish repair shop is the most likely trouble, and one of the hardest for an unskilled owner to detect.

Meshing—It is fairly easy to know in a general way if spur wheels are not meshing properly, that is to say, in more technical terms, if the pitch circles are not touching one another. To begin with, the gear will be noisy. If the meshing be too

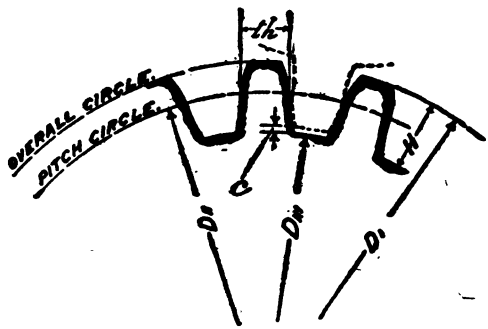


Fig. 1—Showing Overall and Pitch Circles.

deep the tips of the teeth on one wheel will penetrate so far into the spaces on the other wheel that the clearance marked C on Fig. 1 will not exist, and the ends of the teeth will be continually in compression. The obvious general rule, however, is this: Measure the distance between the centers of the engaging spur wheels and divide this into two lengths in the ratio of the number of teeth in each wheel. These two lengths are the radii of the pitch circles, and the pitch circles if described on the wheels would cut each tooth at a little outside of the middle of its engaging face. When two teeth are in full engagement, the line from center to center of the wheels passes through the point of contact of the teeth, and so do both the pitch circles. If teeth mesh badly, whether too

deeply or too little, there is rubbing and crushing of the surfaces and loss of efficiency, particularly with cycloidal teeth.

Shape of Teeth—In (3) the effect of a tooth being a bad shape is that even though the whole width of surface is operative the root or other part of the tooth has been made too thin for the pressure to be transmitted; it is therefore overloaded and snaps. Involute teeth are preferable to cycloidal in the gear-box.

Partial Engagement—In (4) if a careless driver leaves the speed lever in an intermediate position between the notches, or if the quadrant which carries the notches is strained over by rough usage, only a fraction of the width of the tooth is operative and overloading of that fraction occurs, so that either a piece chips off or the metal crushes and flows generally so as to make a burr on the edge of the tooth. If a piece chips off there is grave risk of much expensive damage resulting from the piece, even if quite small, getting jammed between another pair of teeth and snapping either one or other off. The freshly broken tooth may then chance to drop between two other wheels rotating in engagement, and it will ruin them also, whether or not they be transmitting any power. This possibility of damage being done to gear wheels which are rotating idly, by the accidental intrusion of foreign matter such as a flynut belonging to the lid of the box, is a slight drawback to the type of gear-box which employs such idly rotating wheels, apart from the objection to the noise and the waste of power. The latter, however, need not be important if the gear-box be fitted with ball or roller bearings.

Fierce Clutch let in badly—A cause of damaged gear wheels is sometimes the accident by which one's foot slips off the clutch pedal. If it be very fierce, and the engine running fast while the car is nearly stationary, a considerable jar results. It is true that the factor of safety, or the margin of strength of the teeth, ought to be sufficient to allow for all such eventualities as may legitimately occur to a careful driver, but the size and weight of parts is very closely cut in motor cars,

and the design is rightly made as close to the safe limit as possible. A slippery pedal should be roughed at an early opportunity.

Noisy Toothed Wheels—The teeth of gear wheels cannot be engaging each other properly if there is much noise. This incorrectness (if not in the original design) may be due:

(1) To warping.

(2) To wear.

(3) To bad alignment of the axes.

(4) To bad distancing of the wheel centers, especially with cycloidal teeth.

(5) To sliding wheels badly centered on a square shaft.

Warping takes place in manufacture during the process of hardening the surface of mild steel teeth. The expense of grinding teeth after they have been hardened is so great that it is often avoided by the maker, and the hardened teeth are matched with one another after hardening by the process of trial and error till a silent pair is found.

It is well to remember that silent gears on a new car are not necessarily a sign of perfection of the gears, because obviously if the hardening process has been simply omitted there will have been no warping, and the truly cut tooth profiles (machine cut with great accuracy in most cases) will not make any noise till the absence of hardening has been revealed by the rapid wear. As a test of hardening, one cannot cut the face of a hardened mild steel tooth with a file save with difficulty, and the roughness of the file gets polished in the attempt.

Latterly, and in some of the very finest cars, certain peculiar steels with special alloys are used, which are sufficiently hard in themselves, and very tough and strong. These steels do not require to be case-hardened, and though they have not got sufficient hardness to pass the file test they are well able to stand up against the wear of the gear-box.

This fact is mentioned to prevent conclusions being arrived at too hastily by the inexpert. In cases where legal action is being taken on the ground of alleged bad work and ma-

terials, analysis or full mechanical test should be made of the steel.

Noise of Gear Changing—The noise of gear changing must not be confused with the noise previously alluded to made by the gears after the change has been effected. Gear changing with "clash" gear of the sliding type is noisy when the sides of the teeth which have to be pushed past one another are not rounded off, or when the rounded sides have been bruised by the driver using too much force in effecting the change, or by the driver attempting to change without keeping the clutch pedal fully depressed.

Even when the clutch pedal is fully depressed it is important to remember that the light or inner part of the clutch has a certain inertia of its own and tends to continue revolving after it has left contact with the fly wheel. It is only when this movement has reached a certain value that the ideal condition for sliding the gear occurs. That condition occurs when the teeth which are coupled to the road wheels move at the same speed as the teeth which are driven round by the inertia of the clutch and are about to be thrust between them.

To facilitate the getting of this condition during the driving of the car a small brake pad is often arranged near the back of the clutch, so that when the clutch pedal is fully depressed the clutch cone (male part) comes into frictional contact with the brake pad.

A better arrangement still is provided by some designers, who make the male part of the clutch and the gears to which it is connected of such small size and light weight that they have but little inertia and therefore easily take up any speed or change of speed which may be impressed on them by the gear wheels they are lightly put into contact with.

Broken Toothed Wheel—If it is not convenient to get into touch with the maker of the car (as often happens when one is in a distant state) the correct replacement of a broken gear wheel is a difficult matter. It will be facilitated by sending to the best local gear cutter either a broken part or a "rubbing" on paper made from the profile of the tooth, provided

such profile be not rounded off, accompanied by a dimensioned sketch of the gear wheel and stating the number of teeth. One tooth may with advantage be roughly sketched, and the dimensions carefully taken and indicated on the sketch.

The dimensions given must be (referring to Fig. 1) as follows:

DI. The diameter of the overall circle, or of the "pinion blank."

DII. The diameter of the wheel at the pitch line.

DIII. The diameter of the circle at the root of the teeth.

H. The height—(that is, the working height inclusive of the clearance C).

(th) The thickness.

It will be seen that the essential thing to find is the pitch-line diameter.

The depth and width of the tooth must also be given.

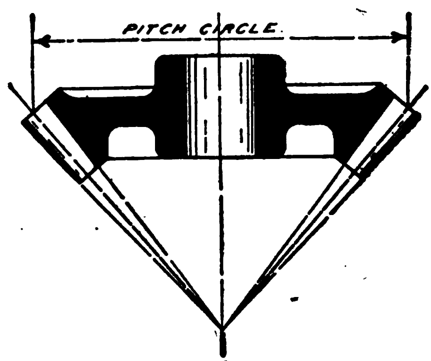


Fig. 2—Showing where to measure the Pitch Circle.

For bevel wheels the same dimensions are required taken from the thick end of the tooth, the pitch circle being as shown in Fig. 2. The angle of the cone must also be given. This is the angle subtended by the pitch circle (Fig. 2).

The bevel in live-axle cars is the toothed wheel which is most frequently weak in design, or at least cut too fine as to its margin of safety

CHAPTER XII.

SHAFTS.

Shafts—A shaft in machinery is a revolving member which transmits power. Shafts are of different types to suit the different conditions under which they work. The shafting in a machine shop affords a good example of the simplest form. A shaft used for this purpose consists of a long length of plain cylindrical steel upon which pulleys are mounted which drive the machines, or other shafts, by means of belts. The principal shafts used in motor-car construction are as follows:

Camshaft—A revolving shaft carrying cams. In the case of motor cars the term is applied to the half-speed or two-to-one shaft which carries the cams operating the valves or low tension magneto mechanism for breaking contact.

In a typical camshaft for a four-cylinder engine the shaft is turned, with its cams and collars, from one solid piece of steel, all the bearing and wearing surfaces being ground true after the shaft is hardened. There is a tapered end, to which is fitted any appliance which has to be driven by the cam shaft, such as the pump or fan. At the other end is the gear wheel, which is driven by a pinion on the engine shaft half its size, and so drives the camshaft at half the speed of the engine. On the inside of the gear wheel are two lugs, to which the governor balls are pivoted. Two collars solid with the shaft locate it in its bearings and prevent it moving endways. In the center of the shaft is a helical or skew gear wheel which drives a similar wheel on a vertical shaft, at the top of which is mounted the contact maker. The cams are eight in number, four of them operating the inlet valves and four the exhaust valves.

The reason for calling the camshaft a "half-speed shaft" is that the shaft is driven by means of gearing at half the speed of the crankshaft, as described under Internal Combustion Engine. That is to say, for every two revolutions of the crankshaft the camshaft only makes one. It is only necessary to operate each valve once during every two revolutions of the crankshaft, and this method of gearing is employed to lift the valve at the correct time. The camshaft is also used to vary the lift of the valves, or to give half compression in the cylinder head. In the case of low tension magneto ignition the contact breaker is operated by cams in the same manner. Also the ordinary contact maker or make-and-break device for high tension ignition is usually driven by the cam-shaft.

Cardan Shaft—Where two shafts are not in line with one another, or when their position in relation to one another varies, and one has to drive the other, an arrangement called an arbor or cardan shaft is used to connect the two. This shaft is fitted with universal joints at each end, so that it can adapt itself to the inequalities of the drive. Cardan shafts are also used to transmit power from the gear box to the rear live axle, and are then sometimes referred to as propeller shafts.

Countershaft—An intermediate shaft, taking power from one shaft and transmitting it to another by means of chains, gearing or belts. The term is usually applied to the shaft which crosses the car and carries the chain sprockets on its extreme ends, being driven by means of bevel wheels from the gear box. The term is also applied to the secondary or lay shaft in the gear box. Also called Jackshaft or Cross Shaft. See Secondary Shaft.

Crankshaft—The shaft which receives the impulses of the piston, the cranks converting the reciprocating motion of the pistons into rotary motion. The throw of the crankshaft is the distance between the center of the crankshaft and the center of the crank pin, this distance being, of course, half the

stroke of the piston. The power from the crankshaft is usually transmitted to the gear-box via the clutch.

Cross Shaft—A shaft which transmits power from another shaft while its axis is at an angle to the axis of the shaft driving it. It is a term usually applied to the countershaft of a car.

Engine Shaft—See Crankshaft.

Flexible Shaft—A means of connection between two members capable of transmitting power from one to the other through any angle or angles whatever. It usually takes the form of a tubular spiral through the bore of which runs a flexible wire. The outer tube is fixed at each end, while the power is transmitted by the inner wire. It is used to a great extent in speedometers. A chain sometimes takes the place of the inner wire when the bends are not too acute. In the case of pumps, the spindle is sometimes driven by using a stiff spiral spring as a shaft between the pump spindle and the shaft driving it. In this case, should the pump itself jam for any reason, the spring will relieve the shock.

Gear Shaft—A gear shaft carries gear wheels or pinions which mesh with gear or pinion wheels carried on another shaft. In a gear-box, for instance, there are usually two gear shafts, one called the primary, being connected to the clutch and thus receiving its power from the engine, the other called the secondary, lay or countershaft, being connected to it by gear wheels and transmitting the power to the road wheels. See Change Speed Gear.

Half-speed Shaft—See Camshaft.

Hollow Shaft—Many crankshafts are now made hollow, as also are some other shafts, such as rocking shafts.

Intermediate Shaft—A term applied to any shaft which transmits power from one shaft to another either by means of belts or gears. The name is generally used in connection with the secondary gear shaft. (See Secondary Shaft.)

Jack Shaft—Same as Countershaft or Cross Shaft.

Lay Shaft—The same description applies to Lay Shaft as to Intermediate Shaft. See Secondary Shaft.

Motor Shaft—See Crankshaft.

Primary Shaft—The shaft in the gear-box which takes its power from the engine and transmits it to the secondary shaft. See Change Speed Gear.

Propeller Shaft—This is the shaft which transmits the power from the gear-box to the back live axle. It is provided with universal joints at either end, so that it can adapt itself to the varying angle between the gear-box and the axle due to the motion of the springs. See Secondary Shaft and Transmission.

Reversing Shaft—The small shaft in the gear-box which carries the reversing gear wheel; really an intermediate shaft.

Secondary Shaft—The shaft in the gear-box which transmits the power from the primary shaft to either the propeller or countershaft, or back to the primary shaft. See Transmission. It is sometimes called a lay shaft, countershaft, intermediate shaft, or gear-shaft.

Torsion Shaft—The shaft that runs through the center of a live axle transmitting the drive from the differential gear in the center of the axle to the road wheels. This shaft is really the "live" part of a live axle, the tube or axle proper through which it runs being used solely to support the springs on which the body rests.

Transverse Shaft—A shaft set at an angle to another shaft. The countershaft is a transverse shaft.

Two-to-one Shaft—Same as camshaft.

CHAPTER XIII.

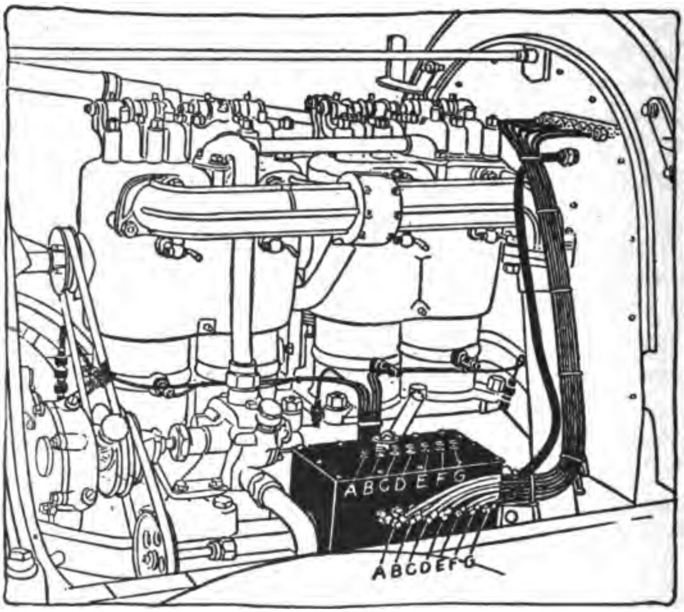
LUBRICATION AND LUBRICATORS.

In practice the lubricant not only serves to separate the surfaces but also helps to carry away the heat generated in the bearings by transfering it to. the cool outer walls of the crank case from which it is radiated to the outside air. With bearings having heavy loads on a limited area the temperature is much reduced by having a large volume of oil continually pouring over the shell, an amount greatly in excess of that required for the maintenance of the oil film.

In general, the bearings of an automobile are supplied with oil by three principal systems: (1) Forced feed. (2) Splash system. (3) Oil and grease cups. In many cars all three are used in conjunction so as to fully meet the varying conditions demanded by the different types of bearings. The familiar grease and oil cups are used for the slowly moving parts that are not in continual use such as the brake shafts, spring shackles and steering knuckles, or for parts that only swing through small angles and have limited travel. The rapidly moving and load carrying parts such as the crank-shaft bearings, connecting rod ends, cam shafts and piston are lubricated by either the pressure feed or the splash system. As the amount of oil required by a heavy duty bearing depends both upon its speed and the load it is usual to have the supply controlled by varying output of the pumps or by varying the amount of oil deposited.

In the force feed system the oil is forced into the bearings directly by means of a high pressure pump. This pump being driven by the motor, feeds the oil in direct proportion to the motor speed but the quantity is independent of the power developed. Oil is fed a drop at a time but at such a pressure

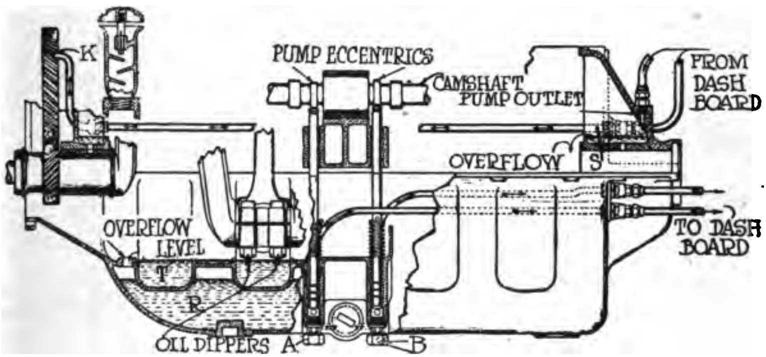
that it is forced into the innermost parts of the bearing surface, thus insuring minimum wear of the parts. There is generally a separate pump and oil lead to each bearing, the separate pumps being mounted in a separate case carried either on the motor or on the dash board.



FORCE FEED LUBRICATING SYSTEM, SHOWING PUMP AND FEED TUBES.

The splash feed system, as its name would suggest, supplies oil to the bearings within the crank case in the form of a spray which is developed by the ends of the connecting rods striking in a puddle of oil. The oil spray is deposited on the interior of the cylinder and reaches the crank and cam shaft bearing through collecting pockets cast in the crank case. The excess oil which drips from the bearings drops to the oil sump in the bottom of the crank case from which it returns to the oil

pump located in the rear of the crank case. Leads from the pump return the oil to the splash puddles, thus using the oil over and over again until it is exhausted. In some cases the oil from the pump is first lead to the bearings from which it drops into the splash pockets, the splash being depended on only for lubricating the cylinders. After overflowing from the splash pockets the oil returns to the pump. The oil pump

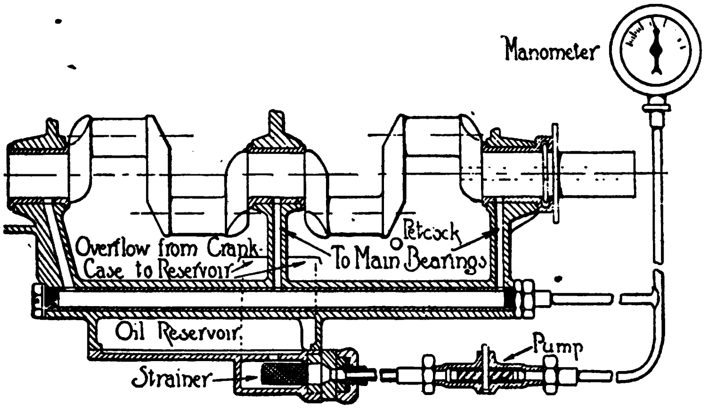


CONTINENTAL SPLASH SYSTEM.

is usually of the gear type although in some cases, a plunger pump is used which is driven from the cam shaft. This system supplies a large quantity of oil but is not easily regulated, and is not well adapted to the modern high speed eight and twelve cylinder motors.

With the force feed system the pipes from the pumps generally lead to the main bearings, the connection rod ends being supplied from the bearings by means of longitudinal holes drilled in the crank-shaft. In some systems the cylinders are fed individually by separate pump leads while in others the drip from the bearings is used in the splash pockets to oil the cylinders so that in the latter system we have a combined force feed and splash. In a sort of semi-force feed system, the oil for all bearings is furnished by a single gear pump that maintains a pressure of from 10 to 50 pounds per square inch on the oil pipes. The gear pump is located in the crank-case

and delivers oil to the main bearings and cam shaft. The oil drip from the bearings reaches the lower connecting rod bearings through holes drilled in the shaft and the excess from this point reaches the piston pin through a tube running from the lower connecting rod bearing to the piston pin. An automatch blow-off valve regulates the pressure in the system and discharges the excess oil to the cam shaft gears in front



GEAR PUMP LUBRICATION.

of the crank case from where it returns to the pump. There are no splash cups.

In the splash feed system it is usual to feed the lower end bearings of the connecting rods through holes in the dipping end of the rods, the force of the impact on the oil puddle creating enough pressure to drive the oil into the bearing. The piston pin is fed by the oil sprayed into the head of the piston or by the oil scraped off of the cylinder walls as the piston moves to and fro in the bore. The rod ends throw oil into pockets over the main bearings from which the oil flows through drilled holes into the brasses. The shaft is not drilled. The return oil from the bearings is circulated by a gear or plunger pump. In some motors, notably the Knight, the splash troughs are pivoted to the crank case and connected with the throttle in such a way that the trough rises when the throttle

is opened. By this arrangement the amount of oil fed is proportional to the power developed by the motor as the rising troughs cause the connecting rods to dip more deeply and hence to throw more oil.

When plunger pumps are used they are driven from the cam shaft by an extra cam, the cam forcing the piston against the oil while the return stroke is made by spring. These pumps work well up to 1800 revolutions per minute (Crankshaft speed) but are likely to jump strokes at anything higher. The principal trouble with a plunger pump is that if dirt accumulates in the valves the oil supply is stopped, but with proper strainers this trouble is almost negligible. Gear pumps are the simplest, have no valves and can be run successfully at almost any practicable motor speed. The latter, however, are not capable of as high pressures as the plunger type are, cannot exert the same force on an obstruction in the pipes. Oil strainers must be provided with all systems and should be regularly cleaned from the accumulated grit and dirt.

Lubrication of Differential.

The differential housing should hold the lubricant in the rear axle gears. Sometimes a disagreeable looking rear axle is noticed where the oil or grease oozes out through cracks or leaks in the rear cover plate or through the axle tubes on the wheels. This is not so common a fault now as it used to be when axles were not designed so well to trap the oil and keep it where it belongs. However, an occasional careless driver will let his axle get in this condition by not having a proper gasket between the differential housing cover plate and the housing itself. It is not much trouble to cut a gasket and it saves much in the appearance of the car and health of the axle gears.

In some cases, a heavy transmission oil is recommended for the axle, but in most instances it is best to use either a semifluid grease or even a heavy grease. It is next to impossible to give any fixed rule for rear axle lubrication. There are so

many designs, and where a heavy oil or a grease will work satisfactorily in one instance, some other form is better in another.

Lubrication of Gear Box.

Parts that are inclosed require attention less often than those that are exposed. The gearbox will hold its lubricant for quite a long time, requiring attention every 2,000 to 3,000 miles or such a matter. In filling the gearset, put in a lubricant to a depth about half the height of the gearbox. Have it come about even with the center of the main shaft. This will completely submerge the countershaft in the average gearset. It is important to see that the packing rings are tight and prevent leakage where the shafts emerge from the gearcase. If there is leakage here, it will act as a collector of dirt and dust, and the gears will be robbed of their lubrication. It is important in lubricating the gearset that the oil or grease should not be too heavy, for in that case it will stick to the gears and be thrown from them by centrifugal force. Very soon, they are free of the very lubricant they have been acting upon and soon run hot. The best lubricant is a heavy oil that will run, or a grease of such consistency that it will flow. There are many special forms of gearset semi-fluid greases and heavy oils on the market. It is obviously wrong, therefore, to put any common grease into a gearset, for it not only acts as above, but has not the ability to get into bearings like a fluid material.

Oiling Schedule.

The majority of manufacturers now furnish some form of oiling chart on which the oiling points, quality of oil and intervals are plainly marked. Careful attention should be paid to this diagram, and should be committed to memory at the earliest possible moment if good car service is to be expected. Never neglect the smallest or most insignificant oil hole for it is there for a purpose.

The following table gives general information in regard to lubrication that will be of benefit in default of the maker's chart. For this we are indebted to "Motor Age."

GENERAL OILING SCHEDULE.

Parts to be Lubricated Daily.

Joints on steering drag link. Grease or graphite.

Clutch collar and thrust bearing. Grease or graphite.

Spring bolts. Grease or graphite.

Tie rod and king bolts. Cylinder oil.

Fan bearing lubricant. Cylinder oil.

In most of the cases mentioned above cups are provided. Besides those listed the crankcase should be brought to level and the tank should be filled with oil.

Parts to Be Lubricated Every 300 Miles.

Steering gear case. Grease or graphite.

All brake clevises or joints. Cylinder oil.

Steering post. Cylinder oil.

Hand and foot brake shafts and pedal bearings. Cylinder oil.

Commutator cleaned and given few drops of cylinder oil.

Parts to Be Lubricated Every 500 Miles.

Spring leaves. Cylinder oil or graphite.

Auxiliary motor shaft couplings. Graphite or good grease.

Add libricant to gearset. Grease or gear oil.

Drain, clean and refill crankcase. Cylinder oil or deflocculated graphite.

One drop of oil on magneto distributor and oil holes provided. Cylinder oil.

Motor timing gears. Cylinder oil, semi-fluid oil or graphite.

Parts to Be Lubricated Every 1,000 Miles.

Drain, clean and refill all transmission gear cases. Same as above.

Repack universals. Grease or graphite. Torsion tube, radius rods, etc. Grease or graphite.

Clean and repack front and rear wheel bearings. Grease or graphite.

In the winter use cylinder oil for the gear compartments instead of grease or graphite.

There is much misinformation about the caring for and lubrication of a disk clutch. Heavy oil often is put into such a mechanism with rather disastrous results. At the end of a reasonable distance, say 500 miles, the old oil in a disk clutch should be removed. There is usually a drain plug fitted to the clutch housing and this should be removed to let the oil out, after which the clutch should be rinsed with kerosene, and again allowed to drain completely. Thus cleaned, a supply of a light clutch oil should be put in until the level is about even with the bottom of the clutch shaft. This allows the plates to pass through a bath of oil, and is the desirable condition.

Drip Feed Adjustment.

A little item of great importance which is often overlooked has relation to the adjustment of drip lubricators. The practice is too common of leaving these appliances just as received from the makers, with the result that the frequency of the dripping varies in accordance with the viscosity of the oil used. A lubricator may be set to supply accurately a sufficient and not excessive quantity of one particular kind of oil, but when upon a tour some different brand of oil may be purchased which will not drip through the orifices of the lubricators with anything like the freedom of the oil for which the lubricators have been adjusted, with the result that the engine receives an inadequate supply; or an oil of a much lighter body may be purchased which will drip through so rapidly as to smother the sparking plugs and valves.

On Lubricating Oils.

In a number of motors, although the compression is good, power is not developed in accordance with the size of the cylinders, and there appears to be a decided tendency to

overheat in the engine. This is often due to using a lubricating oil that is not suitable for the type of engine, as it is found that an oil which gives good results with one type is worthless with another. An oil may appear thick, and yet under the heat and working conditions may thin out to such an extent as altogether to lose its lubricating quality. If this is experienced with water-cooled motors, a good brand of oil usually employed for air-cooled motors should be tried. The results will be found to give satisfaction in most cases.

Heavier Lubricating Oil for Summer.

Each summer complaints are heard as to overheating of engines. In a number of cases this is no doubt largely due to the employment of the wrong kind of lubricating oil for summer use. For water-cooled motors it is not a bad plan in such cases to use oil recommended for air-cooled motors, as this oil is much thinner in summer when in use, and consequently becomes about the right consistency for the proper amount of feed during the summer months. Of course, as the weather becomes colder the usual brand of lubricating oil should again be used.

Over-lubrication.

When a thick cloud of blue pungent smoke is ejected from the muffler it is a sign that there is too much oil in the engine. While it must be admitted that this is good for many engines, especially when new, it must not be forgotten that such an emission is highly objectionable to everybody but those in the car. A simple and effective method of correcting this trouble is to open the compression cocks, when such are fitted, one by one. This quickly clears the cylinder, and with a surprisingly small amount of attendant mess when there is a clear way for the ejected oil. With a single-cylinder engine it is, of course, necessary to give the piston the necessary movement by hand. It is a somewhat extraordinary thing, but many engines will run with quite an overdose of oil without trouble, while others have a very decided objection to a too liberal supply of lubricant. For instance, a Daimler car requires but

a small amount of oil, while, on the other hand, a Mercedes simply gloats on a full charge. Many makers adopt the expedient of fitting an overflow pipe in the bottom of the crank chamber to prevent the engine getting more than is good for it.

Take Nothing for Granted.

Nothing should be taken for granted in the lubrication of an automobile. Everything should be done to make the work of lubrication as easy as possible by having every convenience at hand. The plugs and cocks designed for the drawing off of the spent oil from crank cases should be looked after carefully to see that they cannot work loose while running. If an undue amount of oil drips from any particular point of the vehicle, it may indicate either that the supply is excessive, that means for retaining it are not proper or that the oil is too thin. Thick oil, on the whole, gives little trouble from working out of bearings, especially when everything is worn. The cleaning down of a car is a duty which no one having the instincts of a mechanic will shirk, as the dust which an excess of oil on the outside surfaces of the wearing parts is constantly collecting may prove very injurious to the mechanism.

Preserving Oil Holes from Dirt.

Most users of cars are very neglectful in their oiling of short shafts such as brakeshafts, clutchshafts, and the like. They simply think that these parts can be left to take care of themselves, whereas they should be lubricated as regularly, although not so frequently, as the gear-box bearing or road-wheel bearings. As a number of brake spindles are carried on cast bosses which readily lend themselves to the fitting of clip rings over the oil holes, these clip rings, such as are usually fitted to the hub of a bicycle wheel, should be fitted over the oil holes, and thus no dirt or wet can be allowed to get in the shaft bearings. The brakes work much more sweetly and also clutchshafts have less friction, so that less effort is required to depress the clutch or apply the foot brake. Cases have been known of a rear brakeshaft which was ab-

solutely rusted solid in its place, and could not be moved at all; thus the rear brakes were rendered quite useless through simple neglect of fitting clips and oiling the parts regularly.

Kerosene Pump Lubricator.

If your car is unprovided with means by which kerosene can be injected into the cylinder, and the latter is not fitted with a compression cock, have a kerosene pump lubricator fitted to the dashboard with a delivery pipe, or, in the case of multiple cylinders, forked delivery pipes to the lubricating pipes, as close to the entrance of the latter to the cylinder as possible. The cylinder oil pipes must be provided with cocks just above the junction of the kerosene pipes, so that by turning off these before you do your kerosene pumping on coming in from your run, the latter oil is not forced back, as it may be, into the cylinder oil tank. Above all, do not forget to turn these added lubricating oil cocks on directly after you have flushed with kerosene. Forgetfulness in this particular may mean seizing, with all its horrors.

Cleaning Grease Pipes.

It is not often that grease pipes require clearing out, for which we ought to be duly thankful, for if the pipe be of any length, or contain complicated turns, then there are great possibilities of trouble. The best way to start is to pass a piece of stiff wire through the grease in the pipe, if possible, and if this may be done, then lay the pipe in a tray and keep it covered with gasolene. This treatment will soften the grease, and clear some of it out, so that the pipe may be charged with successive doses of gasolene and cleaned like a bottle. If one is lucky enough to have access to a steam boiler, then the pipe may be cleared by attaching it to the blow-off cock on the water gauge. It needs caution, however, when following this method of procedure, or scalded hands or worse may follow. The safer plan is most certainly that first outlined, but the latter is much quicker and cleaner.

For cleaning out the small pipes, a very good method is to use a pump made out of a bicycle tire inflater. this being pro-

vided with a brass nozzle with a coned end, so that it can be put into the end of the pipe and the contents vigorously discharged through it, thus dissolving and clearing away any congealed oil or other obstructive matter.

Grease Injection.

Some cars require grease to be injected into most inaccessible places. We have in mind a machine which takes grease for its differential and for its two-to-one gear through holes of one inch in diameter, these holes being covered with screw plugs. Now, to push sufficient grease through these small orifices is a dirty and almost interminable task. The owner overcame the difficulty by pressing into service an old grease lubricator of the screw-down type. This lubricator was a gunmetal pot about four inches wide and as many deep. In the screw lid there is a piston with a screw handle, so that when the pot is filled with grease it can be forced out by turning the handle round. At the bottom of the pot there is a piece of copper tube eight or ten inches long, so there is nothing easier than to insert this tube into the holes and then to screw down the lubricator, thus emptying its contents into the gear-box.

It may be interesting to add that we have found the easiest way to handle grease, when one is filling the pot or putting a considerable quantity into the change speed gear-box, is to use a small garden trowel kept especially for the purpose, and entirely free from grit. This is a very clean and quick method of dealing with 8 or 10 lbs. of grease, and infinitely more satisfactory than the ordinary way of picking up small pieces on the end of a flat piece of wood, or digging one's hands into the mess and throwing it handful by handful into the box.

Care of Grease Lubricators.

Pressure should always be kept on screw-down feed lubricators serving grease on to bearings. Owners should get into the habit of giving the caps of the lubricators an eighth, quarter, or half-turn frequently. Overmuch is vastly better than too little lubrication in such bearings as are so served,

When taking over a new car, make certain that the grease lubricator has been filled and screwed down, and filled and screwed down again and again, until the grease is really serving on to the bearing, for in some cars the pipe leads from these lubricators are so long that several charges of the lubricator are necessary to fill the pipe before the grease really reaches the bearing. New bearings have seized or stuck before now for lack of this precaution.

It is often noticeable that the ordinary screw-down lubricator is very hard to manipulate. This is due to the feed-hole at the bottom of the lubricator being too small or to the lead pipe communicating with the bearings having too small a bore. There is no reason why screw-down lubricators should be made so difficult to operate; this matter really deserves more attention from the manufacturers and those who have to use them. The screw portion should be capable of being easily twisted round by means of the thumb and forefinger, and not have to be forced down with the hardest stress which can be put on with the hand or with a spanner.

Commutator Troubles.

Car owners whose high tension ignition systems include a rolling contact maker of the Lacoste type cannot be too careful about the lubrication of the commutator. When cars so fitted are first received from the makers, the interior of the commutator case will or should be found packed with a somewhat thin grease, with which the action of contact-making as the roller on the little arm passes over the brass or steel terminals appears to be as perfect as possible. After four or five hundred miles, the engine may be found to fire imperfectly on one or more cylinders, particularly when accelerated, and then such failures will frequently find their cure by the careful washing out of the commutator with gasolene, and, when the latter has dried off, the application of fresh grease. Care, however, should be taken as to the grease applied, for there are several very stiff kinds sold which, though good enough for bearings, are by no means suitable for commutator lubrication.

An Oil Force Pump.

It is a great convenience to have a force pump for oil on the car—some 7 or 8 inches long, and really well constructed. With this the very thickest of oil can be picked up and injected into almost any part of the car. It is most useful for lubricating many places, and comes in handily in a number of ways. For instance, supposing it is found when on the road that the differential should be lubricated. The arrangement for this in some cars is rather crude, and the only provision for lubrication is to undo a screw plug at the top or the side of the differential casing—we are speaking of gear-driven cars—and it is a long job to empty an oil can into the case, but three or four syringefuls of oil can be injected in a very short time indeed. The pump can also be used for kerosene for cleaning purposes, though, of course, after being so used it should be thoroughly cleaned with stale gasolene before being used again for lubricating oil. The pump can also be used for introducing grease into awkward places. The quickest way to do this is to put the grease in a breakfast cup or small pot, and place the vessel in a pan of boiling water. The grease will then be taken by the pump as though it were thick oil. To prevent the fingers being burned with the hot pump, a thick rag should be used as a protection, especially if the pump has, as it should have, a couple of hooked finger plates at the end of the barrel, as well as a finger ring on the plunger.

Lubricators for Spring Shackles.

Many cars, especially high priced ones, are fitted with lubricators to each of the bearings on the spring shackles. Lower priced cars have merely oil holes, and the user is expected to fill these from time to time. In cheaper cars these oil holes are omitted, but where possible they should be made, as wear sets up in the joints of these shackles and has a tendency to cause rattling after the car has been on the road for a few months. Where the oil holes are provided, and it is desired to close them in some way, this can be done quite easily by the user himself, by means of the covers such as are used

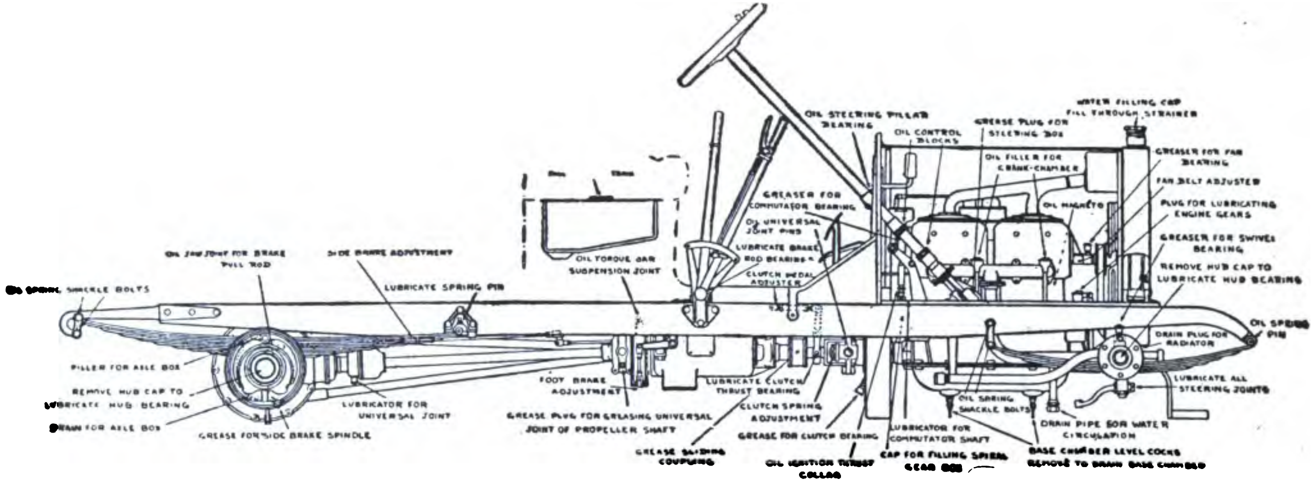
on bicycles. The types we refer to more particularly are the spring bands which are used on bicycle pedals. These can be obtained of different sizes, and can be sprung round the shackle bearings effectually to prevent dust getting in, and yet allow easy access to the holes when necessary.

Good Mufflers and Lubrication.

Where in some cars the muffler has been carefully studied to avoid back pressure, this may have been done so effectually that a very feeble pressure passes to the lubricator, and sometimes on a cold day no feed therefrom can be obtained. When this is so, there are two courses open: The first is to force some oil through the pipes, and that can be done by getting someone to put the sole of his shoe over the exhaust outlet, when the throttle can be opened; the engine will not race, as it will be slowed by choking the exhaust outlet. This will cause the oil to pour through the lubricator sight drip jets in fine style. The second procedure is slightly to warm the oil. This can be done by arranging a leak somewhere, so that the exhaust coming into the lubricator can pass right through for a time, and so gradually get some warm air through. If, however, the lubricator used to feed well, but becomes worse as time goes on, there is another thing to be looked for, and that is, that the oil, for some unexplained reason, has found its way into the oil pipe that connects the lubricator to the large exhaust pipe, and has become crusted up. This has been found the case with many cars under repair, and it is a thing one might look for indefinitely without finding it out.

The Smell from Cars.

There is no need for us to dwell upon the evils of over-lubrication so far as smoke and smell are concerned, but there are some cars which, whether they be over-lubricated or not, always smell more or less, and it will be found that this smell is different from the ordinary odor of burned lubricating oil. In most cases it is due to oil or grease leaking from the gear-box and thrown by the shaft on to the hot exhaust pipe. At this point the pipe may not be hot enough to



LUBRICATION OF A TYPICAL MODERN CAR.

The motor is lubricated from a reservoir on the dash board fitted with sight feeds leading to the main bearings. The oil drips through these feeds, and must be adjusted to feed the right number of drops to each part. The crank should have 8 drops per minute, the connecting rods 10 drops per minute, the cylinders 10 drops per minute, the crank shaft 8 drops per minute. The oil in the base chamber should be maintained at the level of the overflow; it should be replenished and washed out and renewed occasionally. *Daily.*—When preparing a car for a run, one or two drops of oil are required at the following points—valve operating plungers and guides, control levers on steering column, accelerator shaft and joints of throttle levers, clutch on disengaging collar, pin joints of brake mechanism, pin joint of link of torque bar. Each grease lubricator one turn. *Weekly.*—The grease lubricators require filling every week in addition to giving one turn every day before using the car. They are applied to the various parts as follows:—Clutch bearing, universal joint between clutch and gear box, the two universal joints of the propeller shaft, the bearing of the fan spindle, the gear lever and quadrant, the swivels, and the levers and rods of the steering gear, the contact maker, the shaft of the internal expanding brakes, the wheels. The axle caps should be screwed off and filled with grease every two weeks. The box containing the worm and segment should be filled with thick oil or grease every three months through the cap provided. The gear box should be replenished with thick oil through the inspection cover on the top, as required, to keep it full up to one inch below the center of the gear shafts. The bevel gear which drives on to the back axle requires to be filled in the same way. The covers should be removed from all steering connections and re-packed with grease occasionally.

really burn the oil up immediately, but it gradually fries it, and makes a most unpleasant odor in so doing.

The remedy is a simple and obvious one. As a rule, the leakage, if round the primary shaft of the gear-box bearing, cannot be stopped, and the thing to do is to protect the exhaust pipe from the splashes. This can always be done by fitting a thin sheet iron shield an inch or two from the exhaust pipe and between it and the line of the oil splashes.

When driving slowly, too, it has been found that in many cases cars which have the muffler in front of the back axle are much more likely to emit unpleasant odors, of which the occupants of the car are unpleasantly conscious, than if the muffler is fitted further back. The muffler at the back with the final exhaust directed at a slight downward angle is less likely to cause inconvenience. Of course, it will be understood that the angle of the exhaust as it issues to the air will be only slightly downward. It will never beat upon the road, and if a line were taken from it to the road it would not touch the ground till it was at least ten or twelve feet behind the car, so that it has no disturbing effect upon the dust; in fact, if anything, it should tend to reduce dust raising.

LUBRICATORS.

Lubricators—These may be classed under two heads—gravity feed and forced feed.

Gravity Feed.

In gravity-feed lubricators the lubricant is placed in a chamber higher than the point at which it is to be applied, and by its own weight travels down to the oil squeezed from between the surfaces to be lubricated. Even where a simple

oil cup is placed in a bearing it acts by gravity, the oil dropping down to replace that used up.

It is generally considered necessary to provide in this system of lubrication for some form of sight feed, so that ocular demonstrations may be obtained as to whether the oil is flowing or not.

Sight Feed or Drip Lubricators—Generally placed on the dashboard of the car, and immediately under the eye of the driver. The oil drops from the oil chamber through a needle valve, which can be regulated to allow it to pass the oil in the form of drops through a glass tube where the speed of the dropping can be easily seen, and the needle valve can be easily adjusted to cause the requisite number to fall in a given time. A number of these drips or sight feeds can be arranged from one oil reservoir, each one communicating by a pipe to the particular part of the car to be lubricated.

Forced Feed Lubricators.

In forced feed lubricators the oil is forced by a rotating or reciprocating pump, via small tubes, to each journal or bearing to be lubricated. It flows in a constant stream as long as the engine continues to run and to drive the pump. The oil flows over and around or through the bearing or sliding surfaces, and is collected in a drain chamber somewhere below the bearings, generally in a recess formed in the base of the crank case or gear-box for this purpose. It is from this chamber that the pump draws its supply, so that there is a constant circulation of the oil from the oil pump to each bearing and back to the oil pump again.

The feed of the oil from the tank may be either by gravity, as we have seen, or forced. In the latter case the tank may be placed in any convenient position on the car, and the oil is forced from it by air pressure in the tank itself. This air pressure may be obtained by means of a small hand pump, and a pressure gauge on the dashboard indicates to the driver if the requisite pressure is in the tank to keep the oil properly fed to the different bearings.

In another system the pressure of the exhaust gas is used to force the oil through the oil pipes to the various bearings. Part of the exhaust gases are passed through a non-return valve and filter into the oil reservoir, maintaining such pressure as may be required, a pressure relief valve being sometimes fitted to prevent the pressure in the tank rising above a predetermined amount. This system has the advantage of slightly raising the temperature of the oil, and this allows an oil of greater viscosity to be used.

In all cases the oil passes through sight feed lubricators on the dashboard, so that the driver may be assured that this important operation is going on properly. See Internal Combustion Engine.

Forced feed lubrication is also used in some cases on bearings which are fed with heavy grease. In a lubricator of this type the thick grease is contained in a cup which has in its top a plunger pressed down on the grease by a helical spring. As the grease is used up in the bearing and flows away, the spring plunger forces the thick grease down to take its place.

Pump Lubricators—The pump lubricator is almost always of the screw-down grease cup type.

Ring Lubricators.

These are now often used, especially in the bearings of engine crank shafts and the shafts of change speed gears. In this type the center part of the bearing is cut away, forming an annular chamber around the journal or shaft. In this chamber and around the shaft hangs a loose ring of larger dimensions than the shaft. The bottom part of this ring dips in an oil bath in the bottom of the annular chamber, and as the shaft revolves it revolves the ring hanging upon it, which carries around with it the oil from the oil bath, and deposits it over the shaft, from which it runs to the bearing parts at each side of the annular chamber.

Splash Lubrication.

This is used for lubricating the crank pins, gudgeon pins, and pistons of engines either independently or in connection

with drip lubricators or force pumps. In this system the crank case is filled with lubricant to such a height as will allow of the cranks dipping into it at the bottom of each downward stroke. The oil is then splashed upward, and effectively lubricates the whole of the inside wearing parts of the engine. The oil, which is very thick before it is put into the crank case, but becomes thinner afterward on account of the rise in temperature which it there encounters, is forced into the crank case by means of a hand force-pump, generally situated on the dashboard, and provided with a cock, which communicates with the crank chamber, one or two strokes of the piston of this pump supplying oil for a determined number of miles running.

Graphite Lubrication.

A mixture of graphite or plumbago and grease is often used on the chains, chain wheels, and chain sprockets of chain-driven cars, especially in cases where such chains are not protected by efficient chain cases.

CHAPTER XIV.

PUMPS.

Pumps are used in both gasolene and steam cars. The pumps fitted to the latter are described further on in this article under "Steam Engine Pumps." The following types have been adopted in gasolene cars:

Centrifugal Pump—In this pump a number of curved blades fixed to a center boss are rotated in a closed chamber. The

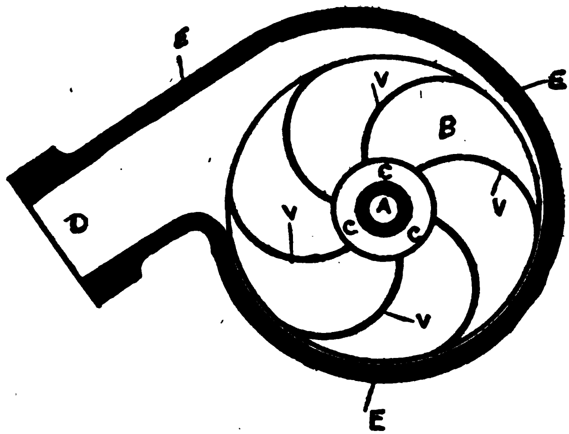


FIG 1—CENTRIFUGAL PUMP.

E E E, Pump casing.
C C C, Suction area at center of fan
B, Fan.
V V V V, Fan blades or vanes.
D, Delivery pipe.
A, Driving shaft.

water is caught by the blades and forced upward to the discharge pipe.

The illustration shows a vertical section of a centrifugal pump. EE is the casing having the tangential delivery pipe at D. B is the fan of the pump having the curved vanes V, V, V, V cast with it. This fan is made with sides and is hollow in the center. It is mounted on a spindle A, which is

rotated at a high rate of speed from the engine either by friction disk or gear wheels. The water enters the center C of the fan, and is ejected from the periphery by centrifugal force along the pipe D, whence it is conducted to the water jacket of the motor. Pumps of this description are reliable, and are widely used for circulation purposes.

The arrangement of the pump and the method of driving it are of considerable importance. The earlier types of centrifugal pumps were arranged to be swiveled on a hinge or joint; they had a friction wheel with a leather periphery, and this friction wheel was kept in engagement with the rim of the flywheel by means of a spring. So long as oil, wet, and dirt could be kept away from the flywheel this pump acted fairly well, but the leather wore and the spring lost its strength, and often the pump slipped and flats were worn on the leather, with the result that sometimes the pump would remain out of operation for a considerable time. Modern pumps are generally geared direct to the engine, and, to prevent trouble through their freezing, or anything jamming the pump, they are fitted with some form of joint which will easily give way so as to prevent injury to the engine, or to the vital parts of the pump. They are also generally arranged so as to be easily detachable for the purposes of examination and adjustment.

In a typical modern method of attaching the pump to the engine, an extension of the crank-case forms a bracket of semi-circular section, and to this bracket the pump is attached by means of a second bracket, also of semi-circular section. When bolted together the two form a kind of half case, in which will collect any water or oil which might leak through. The pump is connected to a camshaft by means of an Oldham joint, a form of the universal joint. A big hexagon nut secures the packing in the stuffing-box. At the top of the pump is the screw-down grease lubricator, and at the bottom is a draincock, by means of which the water can be drawn off when leaving the car in cold weather. This arrangement of the pump necessitates only one water-tight joint, and it

has this advantage also that the front plate which carries the inlet can be easily removed by undoing the hexagon screws that hold its flange in position.

Propeller Pump—A type of pump which has lately come into considerable vogue is the combined centrifugal and propeller pump. In these the vanes of the pump are so arranged that they not only throw the water out by centrifugal action, but act also as a kind of screw, much in the same way as a screw propeller, and push the water along from the inlet to the outlet of the pump.

A good example of this type of pump has the pump casing with the water inlet concentric with it. The water outlet is at one side of the pump chamber. A cover which fits on the flat face of the pump chamber carries a bearing in which is mounted the propeller shaft. On this is the propeller blade, which approximately fits the inside surface of the pump chamber. The shape of the propeller blade is such that water entering at the inlet is forced along by the wings of the propeller both forward and outward, and flows through the outlet, partly by centrifugal action, and partly by the pushing action of the propeller blades. The advantage of both these types of pumps—that is, both the propeller and the centrifugal—is that should anything become jammed or the connection between the pump and its driving power fail, the water may flow through past the blades by thermo-syphonic action, thus to a great extent preventing overheating from pump failures.

Rotary or Gear Pump—Among the direct-acting pumps, that is to say, pumps which actually drive the water in known quantities for each revolution, we have one or two of the rotary type. These are generally known as "Gear Pumps," because they consist of two rotated members gearing with one another always, exactly as two pinions mesh together. These rotate in a closed chamber which exactly fits their sides, and whose outside walls are arranged close to their periphery, so that there is practically no space for the water to pass round them. They are very positive in their action,

and can be driven at high speeds, but they suffer from the disadvantage that should their rotation fail from any cause, the water circulation is effectually stopped, and rapid heating of the cylinder walls naturally takes place. Generally the gears of these pumps are simply two solid gear wheels rotating in the pump chamber, there being no packing of any kind between the edge of the teeth and the walls.

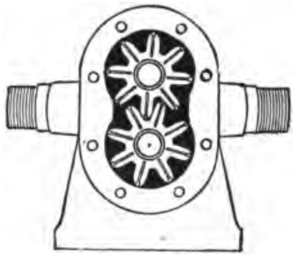


FIG. 2.
THE ALBANY GEAR PUMP.

In Fig. 2 a form of this pump is shown which is typical of its class, with the exception that in this particular pump an ingenious method has been adopted for making what might be called a water-tight joint between the teeth of the pump and the inner side of the chamber walls. It will be seen that each vane or tooth has a narrow slot cut down the center radially, with a rather wider opening at its mouth. When the pump is rotated at a high speed it is claimed that the water which lies in this slot is forcibly thrown out by the centrifugal action, and forms a water joint between the pump vanes and the chamber walls.

Steam Engine Pumps.

Steam Pump—This type of pump is now much used for steam motor cars, both for supplying water to the boiler and for keeping a constant pressure of air in the spirit tank of steam cars. The piston rod of a plunger pump is prolonged into a cylinder and forms the piston rod of this cylinder; or, in other words, a small steam engine is fitted to the water or air pump. The ports of this engine are fitted with valves,

so that when the steam is turned on from the boiler, the valves work automatically, admitting and exhausting steam to and from the engine, which being thus set in motion moves the plunger of the pump backward and forward. As these pumps are independent of the engine driving the car, there is no necessity for the latter to be set in motion to fill up the boiler, etc.

Plunger Pump—This consists of a piston working in a cylinder. Two valves are fitted—one at its mouth. When the pump is operated water is drawn in by the suction of the piston and cannot return. The second valve may be a non-return one, either in the piston itself (in which case the liquid passes through the valve as the piston moves, and during the next stroke is forced by the piston into the required pipe, or the second valve may be placed in the entrance of the discharge pipe, in which case, after the liquid is drawn by the piston into the cylinder, the next stroke forces it through the valve in the discharge pipe against any opposing pressure. The valve then returns to its seat and prevents the liquid returning. This pump may be either worked by hand or connected with the engine, and is principally used in steam cars to supply the boiler.

Hand Feed Pump—The hand pump on a steam car for supplying water to the boiler when there is no steam, or not sufficient steam to operate the steam pump, or where the steam pump has become inoperative.

Double-acting Pump—A pump which draws in and forces out the water or air on both the outward and inward stroke of the piston or plunger.

Force Pump—See Plunger Pump.

Other Pumps.

Air Pump—Otherwise Pressure Pump, and sometimes made in the form of a hand pump. Used for pressure feed in gasolene engines. A pump operated by the engine to supply air pressure to the oil or gasolene tank where pressure feed is used and where the gasolene tank is located at a lower level than the carbureter.

Feed Pump—A pump for feeding oil, water, or other liquid. The term is generally applied to the pump which feeds the water to a steam boiler. Feed pumps may be of practically any of the types of pump described. The illustration shows a type of plunger feed pump sometimes fitted to the steam car. The upstroke or suction of the ram A causes the liquid to be drawn through the check valve D. The downstroke of

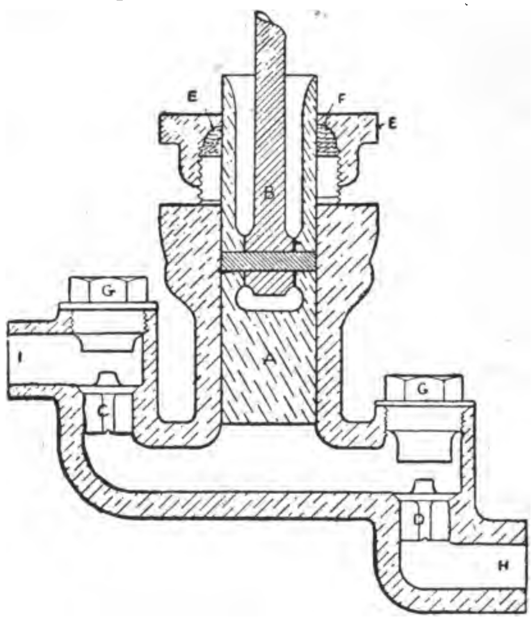


FIG. 3—PLUNGER PUMP.

the ram causes the liquid to be forced through the check valve C into the boiler. G, G are two plugs which allow ready access to the valves C and D. E is a screwed cap, which keeps the ram from leaking by means of the stuffing F. B is the connecting rod which actuates the ram. It is also known as a force pump.

Hand Pump—Any pump worked by hand.

Oil Pump—The oil pump is sometimes operated by hand and somctimes by the engine, and is used to circulate lubri-

cant to the bearings, under force. It may be either of the gear or rotary type, or of the plunger type, but is seldom of the centrifugal type.

Piston Pump—A pump in which the pumping is effected by a piston in a cylinder as distinguished from a centrifugal or a rotary gear pump. Sometimes called a Suction Pump.

Pressure Pump—See Air Pump.

Two-way Pump—A suction pump of the plunger type which has no automatic valves. It consists of a cylinder with a piston inside it, the piston being pulled up and pushed down by hand. The bottom of the pump communicates by means of a two-way cock to the oil tank and to the part to be lubricated. When the cock is turned so as to put the pump cylinder into communication with the oil tank, the plunger or piston is pulled up and oil flows into the pump barrel. The cock is then turned so as to put the pump into communication with the part where the oil is required, and the plunger, being depressed, forces the oil to the place requiring it. It will be seen that it not only acts as a pump, but also as a measure, as the operator can give a whole pump full, or half a pump full, or any quantity he deems requisite. In the case of some cars a compound valve is used, operated by the the handle of the pump itself; an indicator on the top of the pump shows in which direction the oil will be directed so that it can be forced to the crank case, the gear box, or the differential, as required.

Tire Pump—The ordinary air pump for inflating tires. Care should be taken to lay in a stock of "adapters" in case it is found that the nozzle of the pump does not fit the air valve of the inner tube. In this case the adapter has to be used, one end screwing on to the valve, the other into the nozzle of the pump. The necessity for these "adapters" is due to the fact that all pump nozzles and tire valve connections are not interchangeable.

CHAPTER XV.

MOTOR MISFIRING.

Missing Explosions—Whatever the cause, when a motor misses on one or more cylinders the trouble should be located and eliminated with haste. The owner of a four or six-cylinder motor is apt to overlook the fact that missing is occurring or to let it go, with the idea that the trouble will remedy itself. Where the missing occurs because of too heavy a mixture this can be accomplished at increased speed, so as to use up the surplus of gas; but where the cause lies in another direction it is a safe plan to stop and take a little time to do away with the trouble. Prolonged missing may play havoc with the bearings, connecting rods or some other vital part of the motor; it may cause a rupture in the gears and certainly is not pleasant to the occupants of the car.

When a motor begins missing explosions, where before it has been running with regularity, the trouble can as a rule be traced to the ignition system and it is but natural this should be the first to receive attention at the hand of the operator. Even when all things seem to be in perfect working order a motor will continue to miss and it is often a puzzle to locate the trouble. As an instance, a motor that had been running perfectly right along had been put in a repair shop to have a new piece of hose attached to the water system. The priming cocks were so made as to appear to be open when shut—and vice versa. A shop hand, seeing the cocks apparently open, endeavored to close but in reality opened them. Naturally this was overlooked. The motor started readily, but missed

except at high speeds, when it could obtain sufficient gas. Two well-versed men worked on that motor for hours before the difficulty was detected and there was not a thing from carbureter to plugs that was not gone over from one end to the other.

It is a pretty safe rule that if the ignition system is found to be in good order, the attention of the operator should be turned to the carbureter and in all likelihood the trouble will be located there. Still, there are other reasons for a motor missing and they can usually be found in time.

Ignition.

(a) Plugs Fouled or Short-Circuited—When a motor misses, determine which cylinder is at fault by holding down the vibrators of the coil, one or two at a time, so as to cut out some of the cylinders. When the cylinder that is at fault is determined, look to the plug and see if it is fouled or covered with oil or if the porcelain is cracked. If after cleaning it appears to be good, attach the secondary wire, lay the plug on the motor to form a ground and turn the motor over until that cylinder is in contact and a spark shows at the points of the plug. If the spark appears good—that is, purple and reasonably large—replace the plug in the cylinder and run the motor. If the missing still occurs, replace the plug with a new one and try the motor again.

(b) Wire Off—Trace the entire wiring system to see if a terminal is broken, if a connection is loose, if a wire is off at the plug, commutator, coil, battery or magneto, and if the switch is clean and giving a good contact. See that the connections are clean and the binding screws are set down tightly.

(c) Broken Wire—On old cars in particular, the wire within the insulated covering is apt to be broken through twisting or excessive vibration. A broken inside wire in the secondary system will not cause missing; this will occur only in the primary circuit. It is a difficult thing to discover, as when the motor is running without load the ends of the wire are

apt to remain together and form a circuit, whereas if the car is in motion the jolting of the road may separate the ends and break the circuit occasionally if not all the time. New wiring throughout is the best remedy for such a difficulty.

(d) Vibrator Adjustment—Improperly adjusted vibrators will cause a motor to miss. The average owner is apt to do too much adjusting of the vibrators and to screw down the points to not only make a bad adjustment but to cause an excessive flow of current. The tension of the vibrator spring should be sufficient to cause a quick response to the contact but should not be so severe as to provoke a coarse sound. The adjustment of coils is treated in another chapter, which should be referred to.

(e) Switch Loose—A loose switch will permit an irregular contact. It may cause missing on one cylinder or may be the means of stopping the motor entirely.

(f) Weak Battery—A weak battery will not prevent starting and even running, particularly if the mixture happens to be just right for the size of the spark. The missing—and a falling off in power—will become aggravated as the car proceeds, although after the motor has become heated and the car is under way fairly good work will be obtained. The motor, however, will not respond quickly and will tend to choke if the mixture is at all too rich. Where there are two sets of dry cells, connect them all in series as a temporary relief. If there are two storage batteries and both are weak, they can be connected in parallel. It is a good plan to carry an ammeter if dry cells are used. A good dry cel' should show from 15 to 17 amperes to be of service. One bad dry cell will pull down all the others in the series.

(g) Dirty Timer—A timer that has been permitted to run a long time and to accumulate oil, grease and dust will in time give trouble. A timer should be cleaned with kerosene and rinsed in gasolene to remove all particles of dirt. Care should be taken to thoroughly evaporate all gasolene before replacing and starting the motor. The timer should be packed with a good quality of grease after it has been cleaned.

(h) Pitted Vibrator Points—If the points on the vibrator spring or adjusting screw have been neglected for a long time they will be found to have become pitted; or there will be a little hole in one side and a little projection on the other, caused by the action of the current in passing from one side to the other. Where this has occurred the battery wires should be transposed, either at the coil or at the battery, the latter being more simple. It will take some time for the metal projection to leave that side and go back to the side whence it came. It is more than likely this condition will result in the vibrator sticking, and in this case it is advisable to square up the contact points with a very fine file or stone.

(i) Broken Vibrator; Vibrator Point Missing—A vibrator will not work in a satisfactory manner if the spring is either too weak or too strong; if the spring is broken or bent; or if the points have become very badly worn or lost. When any one or more of the conditions are found to exist the simplest remedy is found in new parts, although in an emergency a vibrator spring can be straightened and made to do service. If the platinum point is lost a new point can be made from german silver, iron wire, a piece of silver from a dime or almost any soft metal, even copper. A little piece can be riveted to the vibrator so as to permit the motorist to lose little time on the road.

(j) Condenser Perforated—It is not often this occurs. It may result from a battery being used whose voltage is much higher than is intended for the coil. This can be determined by a test made with a galvanometer and should be made by a coil maker or coil repairer. Where a multiple coil is used and one cylinder gives trouble, the units can be changed about to determine whether the coil is at fault. If, after changing the units, the same cylinder gives trouble the difficulty cannot be charged to the coil but to the plug, timer, or some other part closely allied to the particular cylinder giving trouble.

(k) Coil or Magneto Wet—If the coil or magneto has been exposed to rain, either may have become short-circuited. This will not only cause missing but, where batteries are used, the

battery will run down quickly. Primary coils, where make-and-break ignition is used, can easily be dried by removing and placing in an open oven with a very slow fire. This treatment will not do for jump spark coils, as the heat will melt the wax or paraffin and destroy the insulation. If a jump spark coil becomes wet, it is advisable to send it to the maker to be repaired.

(l) Wires Wet—Where wires—particularly the secondary—are run under the frame of the car, or otherwise exposed to water thrown by the wheels, a complete or partial short circuit is apt to result and cause complete stopping of the motor or a case of violent missing. Where wires are exposed in this manner the operator is advised to preclude the possibility of trouble on the road by protecting them in some manner, such as encasing them in hose.

(m) Ground at the Timer—In old cars, where the primary wire at the timer has been removed a number of times and has become worn, one strand of the wire may become separated from the others and touch some part of the timer, causing a short circuit. This is a common occurrence, particularly where modern terminals are not used or where the terminal has been broken off. One or more strands so touching the timer or other part, forming a ground, may not be in contact at all times and therefore will cause the missing to be intermittent. See that the primary wires connecting the timer are clear of all metal and that the insulation runs well up to the binding posts. It is a good plan to tape the ends of the wire. This will prevent loose ends from causing a short circuit and at the same time will assure a good contact and prevent the possibility of the wire becoming detached from the binding post.

(n) Timer Contact Destroyed—Missing is often caused by a poor contact at one of the points of the timer, either from dirt or oil or from wear on some of the parts. In timers where a roller contact is used, the roller will jump over the contact piece in the insulated part, in part if not wholly, and will give such a short contact as to prevent sufficient current

from passing through the circuit. This can frequently be detected by the motor running well after the plugs have been cleaned and missing as soon as they have become fouled. It is possible to raise the points slightly so as to make the contact longer when the roller passes over them. Care must be used, however, to see that the points are not raised so far as to cause an edge to be felt when the finger is run around the path of the roller on the fiber lining. If a contact piece does become worn, the timer can be taken to a machine shop and turned down on the inside sufficiently to cause the inside surface to be perfectly even.

Carbureter—Mixture.

(a) Mixture Too Lean—Missing, particularly at high motor speed, when the motor is running idle, is generally caused by a lack of gasolene or surplus of air, and is accompanied by a popping back in the carbureter. This is where the float level is correct. If the float level is too low, the same effect will be noticeable. Either a little more gasolene through the medium of the needle valve or a trifle less air will generally effect a cure. See Adjustments, under Carbureters.

(b) Mixture Too Rich—Too much gasolene or too little air will cause the motor to miss, to be sluggish, to cause the car to jerk and to pick up slowly. It will also overheat the motor. At high speed this will not be so noticeable, as the motor will use the excess. To determine this, throw out the clutch and race the motor. If it runs evenly under such conditions, it is strong evidence that the mixture is too rich and the carbureter should be readjusted. See Adjusting Carbureters, under Carbureter.

(c) Air Leak in Manifold—If the nuts or bolts holding the intake manifold to the motor become loosened and permit a slight leak of air, the motor will be hard to start and will miss badly except possibly at high motor speed, in which case there will be a sufficient charge of gas taken into the cylinder. Where an air leak is the trouble the motor will not throttle well and will not develop power under heavy work. If tight-

ening the nuts or bolts does not effect a remedy, a gasket of some thin material, or even shellac, will be required.

(d) Priming Cocks Open—Symptoms the same as in the case above cited. The motor will be hard to start and the motor speed under no load will be excessive. The running of the motor will be accompanied by a hissing sound, caused by the inrush of air.

(e) Restricted Gas Supply—Where the throttle is so set as to restrict the supply of gas, the motor will miss—sometimes only occasionally, according to the supply of gas. The throttle should be so set as to permit the motor to run regularly. If it runs at excessive speed, the mixture is at fault and should be adjusted.

(f) Cold Motor—No matter what the nature of the mixture, a motor will miss when excessively cold and continue to do so until it has become heated. Gasolene will not volatilize readily when cold, and propagation of the gases is slow. Where the motor is cold, also, there will be a firing in the carbureter, because of slow combustion. When the motor is cold and missing takes place, the ignition can be advanced considerably past the normal point until the motor has become warmed.

(g) Valve Spring Weak or Broken—When a valve spring is too weak to permit the valve to seat, or is broken, causing the same trouble, the motor will naturally miss because of its inability to hold gas in the particular cylinder having the troublesome spring. If the valve spring is broken, an iron washer may be placed between the broken ends—and over the valve stem, of course—and the motor will run as well as ever. Care must be exercised to prevent the washer from binding at any point. Where the spring is excessively weak, washers may be used to place a tension on the valve spring.

(h) Valve Stem Bent—A bent valve stem will cause the valve to stick and hold open, permitting loss of compression and preventing suction of gas. The valve must be taken out and the stem straightened. In an emergency this can be done on the road, although it is a mechanic's work. In case of a roadside job, the stem should be laid on a piece of wood

which is slightly concave. Another piece of wood should be interposed between the stem and hammer, otherwise the stem will be so marred as to be unable to pass through the valve stem guide. The blows to straighten should be light, followed by close inspection. When the stem will work freely in the guide, and the valve seats, it can be used. Straightening a stem is apt to unseat the valve and this may need regrinding.

(i) Valve Stem Sticking—A valve stem may stick from being fouled with carbon or gummed with oil, in which case all that is necessary is to clean carefully with kerosene and gasolene. Do not oil valve stems.

(j) Valve Not Seating—This is not usually a cause for a motor missing. It will interfere with obtaining a correct carbureter adjustment, however, and a poor carbureter adjustment will cause a motor to miss, so that indirectly it may be the cause of the trouble. The remedy for this is to regrind the valve until it seats perfectly.

CHAPTER XVI.

NOISES IN THE MOTOR.

Pounding and Knocking—It is not always easy to distinguish between these two terms—"pounding" and "knocking" —in connection with a motor. A pound may be described as a deep-toned, muffled sound, while a knock is sharp and is accompanied by more or less of a metallic ring. The presence of either calls for immediate investigation and elimination, as to be permitted to continue might—and undoubtedly would —cause almost irreparable damage or damage that could be rectified only at considerable financial expense and the laying up of the car for a few days.

Pounding.

(a) Loose Connecting Rod—Remove bottom half of crank case or side plates, according to motor design, and feel connecting rod and crankshaft bearing for looseness. If there are shims between rod and cap, remove one or more so as to bring the cap close against the shaft. This will effect a temporary repair, but as soon as possible the connecting rod and cap should be scraped to insure a good fit. Do not fit the parts so close as to cause them to bind; a little play will be better. When replacing, rub on plenty of lubricating oil; never assemble wearing parts dry.

(b) Loose Bearing—Usually the back bearing. A loose bearing is hard to locate and is usually found through the process of elimination. A piece of ¼-inch steel wire, one end placed between the teeth and the other over the bearing will usually locate the trouble while the motor is running. If the pound is bad, have the trouble eliminated at a good repair shop. Such trouble develops slowly and seldom prevents one from continuing on a journey of reasonable length. Where a bearing is loose the noise is more noticeable at slow motor speeds. In cases of this kind run the motor moderately.

(c) Loose Flywheel—Particularly common where the flywheel is keyed to the crankshaft and not easy to determine. More apt to show when motor is running idle than when clutch is engaged. Where flywheel is bolted to a flange made integral with crankshaft, tighten nuts on bolt ends; where keyed on, drive in key, using soft iron or brass bar between key and hammer.

(d) Preignition—Carbon in cylinders, which keeps aglow from heat of the explosion, will ignite the incoming gas before the piston has passed the top of the compression stroke. This tends to drive the piston downward and against the momentum of the flywheel, thus causing a pound. It tends to spring the crankshaft and wear the bearings. The use of kerosene or carbon remover may remove the trouble to some degree temporarily, but the surest way is to take the carbon out through the valve cage holes in valve-in-the-head motors or by removing the cylinders in other types. Excessive lubrication causes carbon deposits.

(e) Shaft Sprung—A loose bearing, preignition or advanced spark may cause a crankshaft to spring slightly out of true. It can be determined only by removing the cylinders and top half of the crank case and revolving the crankshaft and testing with a surface gauge to determine trueness. To remedy such a disturbance requires the work of a thorough mechanic; better still, send it to the factory which made the motor.

(f) Lost Motion—Looseness in any of the working parts

will cause a pound and can be located only by patient search and through the process of elimination.

(g) Misfiring—One or more cylinders misfiring will cause a decided pound. Locate the cylinder and stop the missing. See chapter devoted to missing.

(h) Unequal Compression—One cylinder with compression weaker (or greater) than the other will cause a pound through being out of balance. Try each cylinder for compression and endeavor—through grinding values, tightening plugs and valve caps—to bring all to an equality.

(i) Restricted Exhaust—A motor which has been overlubricated and permitted to smoke, will foul the exhaust pipe and muffler, causing decided back pressure and creating a pound. If there is a muffler cut-out, open this to determine if the trouble lies here. Clean the muffler by dissembling, if possible, or by soaking in kerosene for several hours. Be careful that all traces of kerosene are gone before assembling and starting the motor. The kerosene may be washed out with gasolene, and should be left to stand over night so the oils will drain out.

(j) Loose Wristpin—Possible but not likely cause. Determined by disconnecting the connecting rod from the crankshaft and moving up and down. If loose, new wristpin bushings in the cylinder constitute the remedy.

(k) Connecting Rod End Slap—Most makers provide for about ⅛-inch end play on the crankshaft end of the connecting rod. Occasionally the bearing becomes rounded, so that on the impulse stroke the rod slips on the crankshaft and causes a slap on the end. It is disagreeable and indicates that the bearing needs attention. It is likely to accompany a loose connecting rod bearing and can be determined in the same manner. Removing shims, however, will not remedy the matter; the bearings, if rounded, must be scraped until they are square with the crankshaft.

(l) Loose Cylinder—Place the hand so as to cover the base of the cylinder and part of top half of the crank case. If loose it will be felt. Set down nuts holding cylinder to base. Do

this occasionally as a good rule to follow on general principles.

(m) Loose Crank Case—May be loose where bolted to frame; bottom half may be loose. Either determined by examination and holding hand on parts when motor is running. Tighten nuts to remedy.

(n) Nut or Bolt in Crank Case—A nut might loosen, drop to the bottom of the crank case and the connecting rod hit but pass same. This is unlikely, as in all probability striking it would break the case instantly.

Knocking.

(a) Spark Advanced—This causes the gas to ignite before the piston has reached the top of the compression stroke—it is preignition and causes a decided knock. Particularly noticeable if motor speed is slow, as in ascending a grade, and spark has not been retarded. Will cause bearings to wear. Spark should be kept in close relation to speed of the motor.

(b) Overheating—Lack of water passing through the water jackets causes the metal to expand and bind the reciprocating parts. Water supply may be short or not circulating. Excessive use of oil might permit a short run only.

(c) Lack of Oil—Very common cause for knocking. Motor will bind if stopped. In this case work a small quantity of kerosene into the cylinders through plug holes and turn motor by hand. Then work in lubricating oil in small quantities until motor is free. See that crank case has oil and that lubricator is working.

(d) Piston Ring Stuck—Caused by over-lubrication and consequent carbon deposits under rings. Remove plugs, inject two tablespoonfuls kerosene in each cylinder, permit it to stand over night, turn motor vigorously by hand—with plugs removed—to eject surplus kerosene.

(e) Preignition—Also causes knock. See under head of Pounding, above.

(f) Push Rod Clearance—Ends of valve stems and push rods—and rocker arms in valve-in-head motors—will wear,

causing too much clearance and a knock. Clearance should be adjusted according to maker's instructions. If too close or too far apart, the time of opening and closing the valves is materially affected.

(g) Timer Slipped—Occasionally the commutator will slip and thereby automatically advance the spark. Thus the necessity for knowing where the timer should be set on the cam shaft. Usually, of course, the tendency is to retard the spark where the timer has slipped.

(h) Loose Cam or Cam Shaft—Loose cams are unusual now, as cams are cut integral with the camshaft. Shaft where keyed to gear may be loose, or gears may be worn to cause slight knock. Not likely. If key is loose, drive in; if gears are worn, replace, as much play affects the time of valve action and ignition.

(i) Loose Pump or Magneto Pin—Pump shafts are frequently driven by a pin; magnetos are thus driven only occasionally. In pump, if packing gland is not tight, driving against pin if loose will cause very slight knock.

(j) Loose Magneto—Fastening of magneto may loosen and cause knock.

(k) Loose Oiler Mechanism—Where mechanical lubricator is driven by ratchet or eccentric mechanism, a worm or loose part will cause a knock, which can be removed only by taking up the wear.

(l) Fan Hitting—Bent fan blades may hit radiator; straighten. Set screw may strike belt; put in shorter one. Belt fastener may slap pulley; replace.

(m) Rocker Shaft Loose—In make-and-break ignition, rocker shaft or pawls may be deranged or loose or worn. Go over and tighten or replace.

CHAPTER XVII.

MOTOR OVERHEATING.

Overheating of the motor may result from a number of causes, which are taken up in the order of probable frequency. Here appears the necessity for knowing the maker's scheme of timing the spark and the setting of the valves, inasmuch as these points may enter into the cause of heating.

Modern motors are not prone to overheating troubles from lack of proper design; they will cause trouble if some adjustment becomes disarranged or the operator does not give some attention to this very important matter. Heating may be divided into several classes, but four will, when properly subdivided, cover the majority of cases. In case of an overheating motor, look for the trouble in the order given below:

Radiation.

Lack of Water—Examine the tank and fill with clean, strained water. Soft water is preferable. Run the motor to remove the air in the radiator and pipes and keep putting in water until filled.

Fan Not Working—(a) Belt lost—Make temporary belt from clothesline, sewing machine belt, wire spring if long one can be secured, or from shoe laces. After using for a while, see that stretch is taken up.

(b) Belt stretched—Take up slack by removing from one pulley and twisting, securing ends as originally.

(c) Belt coated with oil—Remove and wash with gasolene; for temporary job rub on fine sand, being careful that none finds access to the working parts of the motor or other wearing parts.

(d) Tightener slipped—Reset nut or set-screw; if either is

broken, use a piece of wire to hold tightener, attaching wire to some part of the bonnet or motor.

Pump—(a) Pin through driving shaft sheared off—The pin can be replaced temporarily at least while on the road by a wire nail, piece of heavy wire, cotter pin or small bolt. Where this temporary repair has been made with a makeshift pin of soft metal a frequent examination should be made to see that the substitute is holding.

(b) Packing gland loose—If packing material has become lost, replace with a piece of candle wicking soaked in oil or grease. Strips from a handkerchief will do on a pinch. Replace the gland and screw up fairly tight. If the packing gland is loose it is apt to cause an air leak and prevent the pump from doing full duty.

(c) Gears worn—When the gears in a gear pump or the vanes in a vane pump become worn it means a repair shop job of turning down the plates so the sides will be brought closer to the gears. This trouble is not apt to develop suddenly or on the road unless on a long tour.

(d) Pump clogged—Some pumps are protected by a screen, which in time becomes clogged with pieces of rubber disintegrated from the hose or by sediment from the radiator. This will stop the circulation and should be removed.

Other Causes.

Radiator Fouled—Where water containing lime has been used a scale will form and if not removed frequently will cause severe overheating. It is well to clean the radiator three or four times a season on suspicion. A scale remover can be purchased, or a mild solution of lye can be used. Dissolve half a small can of lye in a pail of water, stirring until all is dissolved. Strain and pour in the radiator. Run the motor for a few moments. Let stand 10 minutes and drain off. Fill with clean water, run the motor and drain. Repeat the clean-water operation four or five times. Do not permit the lye water to touch paint or varnish, else the latter will be ruined. It must be remembered that the lye will sooner or later de-

stroy the rubber hose, which must be renewed as occasion seems to demand.

Clogged Radiator—To determine whether the radiator is clogged, disconnect the lower pipe—the one running to the pump—and see if the water flows freely. If not, the radiator is clogged. To remedy this attach a hose and resort to slight pressure to remove the obstruction. If water pressure will not suffice, about 25 pounds of air or steam, the former preferred, will in all probability do the work.

Pipes Restricted—It is possible in replacing water pipes and using gaskets to restrict the circulation of water if the gaskets are misplaced a trifle. Placing gaskets should be done with care.

When replacing hose it is possible to ruffle the inside end with the edges of the metal pipes and to cause pieces of rubber to become dislodged. This should be avoided if the pipes are not to be clogged.

Imperfect Air Circulation—Where the fan is formed by webs in the flywheel the bonnet and pan under the motor must be practically airtight in order that the air may be pulled through the radiator and thus perform its duties of cooling. Holes in the pan or open joints in the radiator will prevent the proper circulation of air and should be stopped up in any manner possible.

Where a motor is so designed that proper vent for the crank case cannot be secured, heating may result; this is not apt to occur in modern motors, however.

Late Ignition.

(a) Timer slipped—Timers are frequently secured to the end of the camshaft or to a vertical shaft driven through bevel gears by the camshaft, by means of set screws. If there is a bind in the wearing parts of the timer and the set screw becomes loosened the shaft will slip away from the proper position and the spark will become retarded, causing overheating and non-responsiveness on the part of the motor.

(b) Gears misplaced—Where a vertical shaft carrying the timer is driven through bevel gears from the camshaft, it is

possible in reassembling to misplace these gears one or two teeth and thus cause the ignition to be retarded and cause heating or to advance the ignition too much and cause a knock in the motor.

It is well to have the timer and the gears marked so they can be correctly replaced.

Carburation—Too rich a mixture will quickly cause overheating, and some good authorities claim that overheating can result from too lean a mixture, although the author has never known of a case. At any rate, it is just as well to have correct mixture as too lean or too rich. Too rich a mixture can be detected by the odor of unburned gasolene and by black smoke from the exhaust. Too lean a mixture can be detected usually by a popping back into the carbureter.

Additional Causes of Overheating.

Tight bearings or tight piston, resulting from either too close a fit or a lack of lubrication, will cause severe overheating as a result of a more liberal supply of gas to make the motor do its work. If it is found this is the trouble a superabundance of lubrication will probably effect a cure, although it may result in sooting the plugs and possibly carbonizing the cylinders.

If the exhaust pipe and muffler become more or less restricted as a result of carbon deposits arising from an excessive use of lubricating oil in the motor, it will cause a back pressure and consequently overheating if not a stopping of the motor. This can be determined by using a muffler cut-out, if one is fitted, to give perfectly free exit to the exhaust gases. Both muffler and exhaust pipe should be removed at the end of a season and thoroughly cleaned.

When the valves become disarranged through error in reassembling and the exhaust is not permitted to find its way out of the cylinder at the time designed, the prolonging of the time for holding the exhaust will cause overheating; thus the necessity for knowing the correct valve setting and having the valves set properly.

CHAPTER XVIII.

ELECTRIC MOTORS.

The electric car is the ideal motor car in certain respects, says an authoritative writer on the subject, and the less perfect in certain others. The chief defect is in the means of supplying energy to the motor. The chief perfection is in the means of applying the energy and controlling it which the motor itself affords.

The continuous torque, perfect balance and high speed of which the motor is capable diminish the stresses on the transmission chains or gear and effect an economy of weight by dispensing with flywheels, gear, etc., which is, however, not sufficient to counterbalance the excessive weight required by the storage cells if these are to have any length of life and to travel for distances comparable to the mileage of gasolene cars. Unlike the gasolene engine, the electric motor may be made to turn at a constant speed regardless of the gradient, or at will at an approximately constant rate of working no matter what speed, within limits. These qualities afford immense advantages which are unobtainable with the explosion engine, though they are reached to a certain extent with those steam engines which allow a variable cut-off. To enable the gasolene engine to work at full power while

the car travels at a low speed, gear which is changed brusquely in steps is resorted to, and to enable the gasolene engine to work at a constant speed, no matter what may be the effort required by the road gradients, requires an efficient system of governing, and further makes it necessary that the engine shall be of such large dimensions as to be able to permanently give what may be only a momentary excess of load.

The electrical connections to the motor, controller and batteries of an electric car, though they require larger conductors than the electrical connections for the ignition of a gasolene car, are in most cases not appreciably more complicated and in many cases are more accessible. This means in practice that the electric car is, to a degree which is not always appreciated, simpler than the gasolene car, or, in other words, the ordinary gasolene car frequently carries in miniature the whole of the complication of the electric vehicle with an internal combustion engine and a gear-box in addition.

Turning from the perfections of the motor and passing to the difficulties which attend any attempt to make portable a supply of electric energy, we find a far less hopeful state of affairs.

The comparison between an electric car and the more usual type of motor car driven from an explosion engine may be briefly summarized as follows:

Advantages of the Electric Motor for Automobiles—1. A rotary engine of light weight giving a large torque at small speeds, able to stand overloads.

2. High internal efficiency of the combination of motor and its speed-reducing gear, if any.

3. A cheap mechanical equipment for speed control, owing to the possibility of dispensing with gear and clutch for change speeds.

4. Cheap maintenance, cheap lubrication, freedom from breakdown.

5. Absence of lubrication troubles, valve troubles, oil, dirt, smell, water-circulating troubles, pumps, cooling radiators, pipes, inflammable material in store, etc.

6. Extreme simplicity—three parts only; motor, controller and battery; ease of finding faults, and ease of measuring power used.

7. Cheap and clean housing; no fire risk compared to gasolene risks.

8. Ease of manipulation; flexibility of control owing to the absence of mechanical links, bell cranks, etc., allowing controller to be placed anywhere regardless of position of motor.

9. Thoroughness of control: reverse for all speeds, motor usable as brake, yet absorbing little power when driven by the road wheels when coasting.

10. No exhaust noises, backfire or muffler explosions.

11. Certainty and ease of starting from the driver's seat by a switch only.

Disadvantages—1. Weight of batteries, which more than counter-balance the advantage here gained on the motor.

2. Cost of battery, which outweighs the cheapness of the electric motor and the cheapness of mechanical equipment.

3. Inefficiency of battery, which outweighs the efficiency of the motor and absence of gear losses.

4. Rapid depreciation of battery, which outweighs the small cost of upkeep of motor, and economies due to having no clutches or gear.

5. Acid fumes and spillage, which may be set against the absence of smell and absence of oiling, and the depreciation by way of dirt which oil brings.

6. Loss of time for recharging, say one-quarter of the useful time.

7. Limited number of charging stations and distance possible on one charge.

8. Occasional necessity for losses in charging due to variety of pressure at different stations.

It will be noticed that the first among the disadvantages is the weight of batteries, and this, taken in conjunction with the volume they occupy, their liability to rapidly depreciate, and their small capacity from the point of view of the num-

ber of miles of country which can be covered on one charge, alone explains the slow progress made by a vehicle offering so many advantages. Another disadvantage of storage batteries is the serious effect resulting from short-circuiting the cells. No automatic protection which can be afforded to the batteries can be looked upon as otherwise then remunerative expenditure, and the lack of success which has from time to time troubled those who have instituted electric vehicle service is very largely ascribable to the lack of such protection.

Distance Traveled—The average electric automobile fitted up as a pleasure carriage for town work is designed to go, when new, about 40 miles upon one charge of the battery. In practice, says the authority quoted above, it is found that, with the loss of battery capacity with use and vibration, the occasional high discharge rates required up hills, and frequent re-starting and stopping in city traffic, the average distance which may be covered day after day by such a car is 30 miles, with the possibility of occasionally doing a little more. Any attempt to largely increase this distance (and many such attempts have been made for the purposes of advertisement of new batteries, etc.) has resulted in either so large an increase of the weight of the car that the proportion of deadweight to useful weight has become excessive, and the wear of the rubber tires has very greatly increased their cost of upkeep, or the battery has received such heavy discharges in proportion to its capacity that its life is greatly shortened and the cost of renewals augmented to a point which is unsatisfactory in ordinary routine work, however effective as an advertisement such long runs may be.

Consumption of Electrical Energy—Roughly speaking, it may be taken that, for town work, with the car in good new condition, the consumption of electrical energy is at the rate of 95 watt-hours per ton-mile taken from the battery in the car. If the road surfaces are exceptionally good and level, and made of good wood paving or asphalt, it is possible to use solid rubber tires instead of pneumatics without loss of comfort, and at the same time to obtain a slightly diminished

consumption of energy, say, to 90 watt-hours per ton-mile. But even if the usual route avoids all important gradients the consumption in town use may be taken as 100 watt-hours per ton-mile on an old and worn vehicle.

Weight—It has been for some time held that with batteries of the type now in general use, about one-third of the total weight of the loaded car should be batteries, the weight of battery being taken complete—that is, including all liquid, boxes, lugs and connections.

Method of Transmission—Almost all possible methods of transmission have been adopted in practice, for example: (1) The direct-coupled motor, in which the motor armature actually forms one piece with the front road wheel. Two motors are used, and the armatures are, by means of the controller, grouped in series or in parallel, according to the speed or torque required.

(2) The single reduction geared motor, in which two motors are used, one driving each front or each back wheel through one spur wheel and pinion; or

(3) The single reduction chain drive, in which one motor is used to drive a chain which passes over the middle element of the differential gear.

(4) The single reduction chain drive, in which one motor is used with the armature rotating in opposite direction to the field. The armature is connected by a chain to one back road wheel, and the field by a pinion and chain to the other road wheel, thus dispensing with the differential.

(5) The worm wheel drive, by which a single motor is placed in the front of the car, and drives a propeller shaft connected by means of a worm wheel to the middle element of the differential gear.

A feature which has unexpectedly turned out to be in favor of the electric automobile is its limited range of travel. This has the effect of obliging the owner to keep the vehicle in some town and there the inducement to him to contract for an inclusive annual sum for the maintenance of machinery, maintenance and painting of carriage work, maintenance of